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DARLINGTON NGS 'A' STANDBY GENERATOR #1 VIBRATION ACCEPTANCE TESTS

Report No 88-241-K

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ABSTRACT

Commissioning tests to determine acceptability of Standby Generator #1 (AC generator and power turbine) dynamic and vibration characteristics are described. Vibration levels and structural dynamic characteristics of the AC generator are considered acceptable. The power turbine has structural natural frequencies close to the operating speed, but casing velocity levels are considered acceptable. The overall shaft displacement level measured at the power turbine inboard bearing exceeds the acceptance limit by 28 percent. A first rotor critical speed of the AC generator - power turbine unit between 1410 rpm and 1540 rpm, as well as possible rotor natural frequencies at 52 Hz and 68 Hz was identified. A theoretical rotor critical speed analysis of the unit is recommended to determine the rotor dynamic characteristics.

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EXECUTIVE SUMMARY

DARLINGTON NGS 'A' STANDBY GENERATOR #1 VIBRATION ACCEPTANCE TESTS

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Mechanical Research Department

As part of the Darlington NGS commissioning program, acceptance tests were carried out on Standby Generator #1 to determine the vibration and dynamic characteristics of the AC generator and power turbine.

The overall bearing casing velocity and shaft displacement levels measured on the AC generator are considered acceptable. The structural dynamic characteristics of the AC generator are also considered acceptable.

The power turbine has structural natural frequencies close to the operating speed which can amplify the vibration. However, the measured velocity levels are considered acceptable. It is recommended that velocity spectra be obtained on the power turbine periodically to assess the effect of the structural natural frequencies. The overall shaft displacement level measured at the power turbine inboard bearing exceeds the acceptance limit by approximately 28 percent.

A rotor first critical speed of the AC generator - power turbine unit between 1410 rpm and 1540 rpm, as well as possible rotor natural frequencies at 52 Hz and 68 Hz was identified. A theoretical rotor critical speed analysis of the AC generator - power turbine unit, to determine the rotor dynamic characteristics, is recommended.

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To

Mr. D.R. McQuade
Technical Manager
Darlington NGS 'A'

DARLINGTON NGS 'A' STANDBY GENERATOR #1 VIBRATION ACCEPTANCE TESTS

1.0 INTRODUCTION

Vibration acceptance tests were carried out on four Standby Generators SG #1 - SG #4, as part of the Darlington NGS 'A' commissioning program. Mechanical Research (Ontario Hydro) was requested to carry out the vibration commissioning program as specified by Pratt & Whitney and Darlington NGS 'A' Operations. This report discusses the results of the tests on Standby Generator #1. The results of the vibration acceptance tests on Standby Generators #2, #3 and #4 can be found in references 1, 2 and 3, respectively.

The principal objectives of the tests were to:

1) Evaluate the acceptability of the machine vibration and dynamic characteristics with respect to Pratt & Whitney's contractual obligations as well as Ontario Hydro's specifications and/or industry standards.

2) Obtain baseline vibration data for use in future machine monitoring.

3) Make recommendations for corrective action if vibration levels are in excess of the limits specified in the relevant tendering documents or specifications.

The general turbine-generator arrangement is shown in Figures 1, 2 and 3. The main components are the gas generator, the power turbine (Rolls Royce) and the AC generator (Brush) with a rated output of 27250 KVA at 3600 rpm.

This report presents the vibration data obtained on the power turbine and AC generator.

2.0 INSTRUMENTATION, TEST METHOD AND MEASUREMENTS

2.1 Instrumentation

The main components of the instrumentation used in obtaining the various measurements are listed in Table 1 and are further discussed in Sections 2.1.1 to 2.3, inclusive.

2.1.1 On-line Vibration Monitoring System

Each turbine-generator unit has an on-line vibration monitoring system which measures the overall vibration levels at selected locations on the gas generator, power turbine and AC generator. The permanently installed vibration transducers and their locations are outlined below :

1. AC Generator - The two journal bearings of the AC generator are equipped with two displacement transducers per bearing, mounted radially at 90 degrees to each other. These displacement transducers (Bently Nevada Model 21505-00-12-60-02) measure the generator shaft motion relative to the bearing housing.

2. Power Turbine - Two displacement transducers (Bently Nevada Model 21505-00-12-60-02) are mounted radially at 90 degrees to each other on each of the two journal bearings, and measure the power turbine shaft motion relative to the bearing housing.

A velocity transducer (Bell and Howell Type 4-103-0001) is also mounted vertically on an adapter plate bolted to the top of the bearing pedestal across the centre line of the power turbine inboard bearing and measures the power turbine inboard bearing pedestal velocity.

3. Gas Generator - A velocity transducer (Bell and Howell Type 4-125-L209) is mounted vertically on the gas generator intermediate casing and measures the gas generator casing velocity.

The signals from the four displacement transducers (installed on the AC generator) and the two velocity transducers are monitored. The vibration amplitudes are displayed by the on-line vibration monitoring system. The shaft displacement amplitudes are measured in units of micrometers peak-peak; and the power turbine inboard bearing pedestal and gas generator intermediate casing velocities are measured in units of mm/s rms. The signals from the power turbine displacement transducers are not monitored by the on-line monitoring system.

2.1.2 Transducers used for Vibration Acceptance Tests

The permanently installed shaft displacement transducers at the AC generator and power turbine bearings in the X and Y directions (Figures 2, 4, 5 and 6) were utilized for the vibration acceptance tests. Their output signals were continuously monitored throughout the tests. The permanently installed velocity transducers were only periodically monitored.

Accelerometers were mounted on the power turbine inboard bearing casing and the AC generator bearing casings in the X, Y and axial directions (Figures 4 and 5) to measure the casing velocities. No velocity measurements were made on the power turbine outboard bearing casing or pedestal.

A photoelectric tachometer probe (Bruel & Kjaer MM 0024) was installed at the exciter end of the generator to provide a reference mark for phase angle and shaft speed measurements.

2.2 **Test Method**

The test procedure for the Standby Generator unit is outlined below :

1. The cold soaked (minimum 4 hours since last run) unit was started, synchronized and the load raised to full load for the ambient temperature, at the maximum allowable rate. The unit was held at full load for approximately one hour. All vibration signals were recorded on magnetic tape during runup and full load operating conditions.

Synchronous speed is 3600 rpm (60 Hz).

2. The load was reduced at the maximum rate and the unit was shutdown.

3. The unit was restarted within 20 minutes of fuel shutoff (hot start) and the load raised to full load for the ambient temperature at the maximum allowable rate. Vibration signals were recorded during runup.

In order to evaluate the unit's vibration characteristics under different loads, the unit's power was decreased from 100% (maximum load attainable) to 0% (synchronous idle) in increments of approximately 25%. Loads of 26 MW (maximum load attained), 20 MW, 13 MW, 7 MW and 0 MW were selected. At each load, the unit was allowed to stabilize before the vibration signals were recorded.

4. From synchronous (3600 rpm) idle, the speed was reduced to the minimum power turbine controlled speed (approximately 88% synchronous speed) then increased slowly to the trip speed (approximately 110% synchronous speed). The unit was allowed to trip and rundown to zero speed. All vibration signals were continuously recorded during this period of speed changes.

5. Structural dynamics testing was carried out with the unit not running.

2.3 Measurements

2.3.1 Overall Vibration Levels

The bearing casing overall velocity levels were determined from accelerometer (Bruel & Kjaer Model 4368, Endevco Model 7707-1000) signals which were integrated to velocity and then analyzed with a Bently Nevada Digital Vector Filter (DVF 3). True peak and RMS overall velocity levels were measured.

Shaft overall displacement levels were obtained by analyzing the displacement transducer signals with the DVF 3.

2.3.2 Velocity and Displacement Spectra

Velocity and displacement spectra were generated from the accelerometer signals (integrated once) and displacement signals, respectively, by performing a Fast Fourier Transform (FFT) on the digitized signal.

2.3.3 Bode Plots

The shaft displacement and casing velocity signals recorded during the periods of unit runup and rundown were analyzed using a computer managed data acquisition and analysis system developed by Mechanical Research, Ontario Hydro. Bearing housing velocity and shaft displacement magnitude and phase, at filtered 1 x shaft rotating frequency, versus generator shaft speed were calculated and plotted (Bode plot).

The Bode plots which show the rotor or casing response in both amplitude and phase as a function of shaft rotor speed, were used to identify the rotor and structural natural frequencies of the power turbine and AC generator.

Bode plots produced using shaft displacement transducer signals may be inaccurate if the signal from the transducer includes any appreciable amount of shaft bow or runout (ie, any deviation in the shaft surface which produces a transducer output which is not related to shaft vibration). For this reason, both uncompensated and compensated (ie, compensated for bow and runout by subtracting the slowroll vector from the displacement vector) Bode plots were produced. Compensation is further discussed in Appendix A.

2.3.4 RPM Spectral Maps

Displacement and velocity spectra were generated from the transducer signals at various periods during runup and reproduced as a three-dimensional RPM spectral map.

2.3.5 Impact Spectra

AC generator and power turbine structural natural frequencies were determined by impact testing. With the unit not running, the AC generator and power turbine structures were excited throughout a range of frequencies (5-500 Hz) with a hammer having an elastomeric tip and instrumented with a force transducer. The input force (hammer) and the motor response (accelerometer signal) signals were fed simultaneously into a dual channel FFT analyzer (Ono Sokki CF 920) which calculated the input and response spectra as well as the compliance transfer function. The validity of the transfer function was checked by the coherence of the input and response signals. The ambient noise was reduced by averaging the results of eight impacts.

All impact tests were performed when the unit was cold and not running.

3.0 RESULTS AND DISCUSSION

3.1 Overall Casing Velocity and Velocity Spectra

Overall casing velocity measured on the AC generator and power turbine at the various loads from 0 to 26 MW are summarized in Table 2 and Table 3, respectively. According to the Darlington NGS tendering document, the lateral vibration level measured on the bearing housings should not exceed 2.8 mm/s rms for acceptance purposes.

All overall velocity levels were obtained from unfiltered (5 Hz - 1000 Hz) velocity signals.

3.1.1 AC Generator - Overall Casing Velocity and Velocity Spectra

The maximum overall velocity measured is 0.8 mm/s rms (1.5 - 1.7 mm/s pk) and was obtained on the inboard bearing casing (Y-direction) at a load of 26 MW (Table 2). Overall velocity levels measured on the AC generator bearing casings are considered acceptable.

Velocity spectra obtained at the six measurement locations on the AC generator for the various loads are shown in Figures 7 - 36 (Table 6). These spectra show that the main frequency components are at one, two and three times the synchronous frequency (60 Hz). The velocity levels at 1 x and 2 x synchronous frequency are listed in Table 2. The highest casing velocity in the X and Y directions is at 3 x synchronous speed (180 Hz) and is due to amplification of the casing response at this frequency by a structural natural frequency at 180 Hz (Figure 177). The maximum velocity amplitude measured at 180 Hz is 0.91 mm/s (inboard bearing casing Y-Axis (26 MW), Figure 35). This level is considered acceptable.

3.1.2 Power Turbine - Overall Casing Velocity and Velocity Spectra

Velocity measurements on the power turbine were only made at the inboard bearing. The maximum RMS velocity measured on the bearing housing is 2.1 mm/s in the X- direction at 0 MW (Table 3). The maximum peak velocity is 4.2 mm/s measured at 7 MW in the X- direction. Overall velocity vibration levels measured on the power turbine bearing housing are considered acceptable.

Velocity spectra obtained on the power turbine inboard bearing housing at the various loads are shown in Figures 37 - 51 (Table 7). These spectra show that the main frequency components are at 60 Hz, 15.3 Hz and 19.5 Hz. Peaks at the latter two frequencies are due mainly to broadband excitation of system natural frequencies. Velocity levels at 1 x and 2 x synchronous frequency are listed in Table 3.

3.2 Overall Shaft Displacement and Displacement Spectra

Overall shaft relative displacement levels measured on the AC generator and power turbine at various loads from 0 to 26 MW are summarized in Table 4 and Table 5, respectively. According to the Darlington NGS tendering document, the maximum vibration of the shaft relative to the bearing casing should not exceed 60 micrometers peak to peak for acceptance purposes.

The sensitivity of the displacement transducers is 7.87 millivolts/micrometer. All overall shaft displacement levels were obtained from unfiltered (5 Hz - 1000 Hz) signals.

3.2.1 AC Generator - Overall Shaft Displacement and Displacement Spectra

The maximum overall displacement level measured is 28 μm p-p and was obtained at the outboard bearing (X-direction) at a load of 0 MW (Table 4). Overall shaft displacement levels measured on the AC generator are considered acceptable.

Shaft displacement spectra obtained on the AC generator for the various loads are shown in Figures 52 - 71 (Table 6). These spectra show that the main frequency component is at 60 Hz. The displacement levels at the 1 x and 2 x synchronous frequency are listed in Table 4.

3.2.2 Power Turbine - Overall Shaft Displacement and Displacement Spectra

Due to the presence of a significant 'glitch' (possibly a flat spot) on the surface of the shaft (inboard end), misleading overall shaft displacement levels would be obtained using direct reading instruments. The overall shaft displacement levels at the inboard bearing were therefore determined using the Ono Sokki CF 920 analyzer in the time mode. Figure 189 shows the displacement time signal obtained at the inboard bearing. Table 5 shows the uncorrected and corrected (for the glitch) overall shaft displacement levels. The maximum overall shaft displacement level is 77 μm p-p and was measured at the inboard bearing at a load of 7 MW. This overall level of 77 μm p-p exceeds the acceptance limit of 60 μm p-p by 28 percent. The overall shaft displacement levels measured at the outboard bearing are acceptable.

Table 4 also shows the uncompensated and compensated displacement level at the inboard bearing at 60 Hz (1 x synchronous speed). The relatively large 'glitch' on the shaft surface resulted in a false 1 x RPM shaft displacement level. Since the glitch produced an output signal that did not represent true shaft vibration, it was necessary to compensate for it. This was carried out by

subtracting the filtered (1 x RPM) slow-roll (500 RPM approximately) vector from the filtered signal at synchronous speed. The compensated values represent the true relative shaft displacement (filtered).

Shaft displacement spectra obtained on the power turbine for the various loads are shown in Figures 72 - 91 (Table 7). All displacement spectra shown in this report are the result of performing a Fast Fourier Transform on the raw vibration signal, that is no corrections for glitch, bow or runout have been made. As such, the 60 Hz component of inboard end shaft displacement level should be taken from Table 5 (compensated value) and not from the spectra.

3.3 Cold Start Runup

3.3.1 AC Generator - Cold Start Runup

Figures 92 - 101 (Table 6) show the 1 x RPM filtered bode plots (500 rpm to 3600 rpm) of the AC generator velocity and displacement levels obtained during the cold start runup. Compensated and uncompensated bode plots are shown for the shaft displacement signals. A slow roll vector at approximately 500 rpm is used for compensation.

The bode plots of the filtered shaft displacements and casing velocities (X and Y directions) show a first rotor critical speed at 1540 rpm (25.6 Hz). The bode plots also show a peak in the response at 1940 rpm (32.3 Hz, Figures 98 and 99) and close to 2200 rpm (36.6 Hz, Figures 92 and 100) due to the presence of structural natural frequencies close to 32 Hz and 36 Hz. These structural natural frequencies were identified from impact spectra obtained on the AC generator bearing casings (Figures 177 - 182).

The filtered (1 x RPM) velocity levels measured on the inboard and outboard bearing casings in the three directions (X, Y and axial; Figures 92 - 97) do not exceed 0.8 mm/s peak during the runup. The maximum filtered compensated shaft displacement levels measured at the outboard and inboard bearings, are approximately 33 μm p-p (Figure 99) and 40 μm p-p (Figure 101), respectively, and occur while passing through the first critical. Amplification factors while passing through the first critical were calculated from the four shaft displacement bode plots. Appendix B describes how amplification factors are calculated. The amplification factors range from 4.3 to 4.4 and are considered acceptable. The American Petroleum Institute Standard 616/4/ recommends that amplification factors should not exceed 8 while going through criticals; factors less than 5 are preferred.

3.3.2 Power Turbine - Cold Start Runup

Figures 102 - 108 (Table 7) show the 1 x RPM filtered bode plots (500 rpm to 3600 rpm) of the power turbine velocity and displacement levels during the cold start runup. Compensated and uncompensated bode plots are shown for the shaft displacement signals. A slow roll vector at approximately 500 rpm is used for compensation.

The filtered (1 x RPM) velocity levels measured on the inboard bearing casing in the three directions (X, Y and Axial, Figures 102 - 104) do not exceed 2.9 mm/s peak during the runup. The filtered compensated shaft displacement levels do not exceed 65 μm p-p (Figures 105 - 108) during runup.

The bode plots of the casing velocities (Figures 102 - 104) show a structural natural frequency at approximately 1090 rpm (18 Hz). This structural natural frequency was verified by the impact

tests. Impact spectra obtained on the power turbine inboard structure show a natural frequency at 17.5 Hz (Figures 185 - 186).

3.4 Hot Start Runup

Bode plots (filtered 1 x RPM) and RPM spectral maps of the casing velocities and shaft displacements measured on the AC generator and power turbine during the hot start runup, are discussed in the following subsections.

Compensated and uncompensated bode plots are shown for the shaft displacement signals. The slow roll vector at approximately 500 rpm is used for compensation. The bode plots show the 1 x RPM filtered amplitude and phase from approximately 500 rpm to overspeed. This runup speed range was achieved by combining the hot start runup (0 rpm - 3600 rpm) with the runup from 3600 rpm to overspeed (Section 2.2). There was a time lapse of approximately 150 minutes between the two runups.

3.4.1 AC Generator - Hot Start Runup

Figures 109 - 118 (Table 6) show the 1 x RPM filtered bode plots of the AC generator velocity and displacement levels obtained during the hot start runup.

The filtered (1 x RPM) velocity levels measured on the bearing casings in the three directions (Figures 109 - 114) do not exceed 1.1 mm/s peak during the runup. The filtered compensated shaft displacement levels measured at the bearings (Figures 115 - 118) do not exceed 50 μm p-p during the runup.

The maximum filtered compensated shaft displacement levels measured at the outboard and inboard bearings are approximately 48 μm p-p (Figure 116) and 36 μm p-p (Figure 118), respectively, and occur while passing through the first critical speed at 1484 rpm (24.7 Hz). Amplification factors for the first critical, calculated from the four shaft displacement bode plots, range from 3.4 to 4.4 and are considered acceptable.

The difference between the 'hot start' rotor first critical speed (1484 rpm) and the 'cold start' first critical (1540 rpm) can most likely be attributed to temperature effects (different rotor and bearing oil temperatures) which may alter the rotor dynamic characteristics.

The bode plots of the bearing casing velocities and shaft displacements in the X and Y directions (Figures 109, 110, 112, 113 and 115 - 118) show a steady increase in vibration from approximately 3600 rpm to overspeed. One explanation for this is the possible presence of a rotor natural frequency just above 65 Hz (3900 rpm). The peak in the response close to 2000 rpm is due to the presence of a structural natural frequency as discussed in Section 3.3.1.

RPM spectral maps of the bearing casing velocities and shaft displacements (uncompensated) obtained during the hot start runup are shown in Figures 126 - 135 (Table 6).

3.4.2 Power Turbine - Hot Start Runup

Figures 119 - 125 (Table 7) show the 1 x RPM filtered bode plots of the power turbine velocity and displacement levels obtained during the hot start runup.

The filtered (1 x RPM) velocity levels measured on the inboard bearing casing in the three directions (Figures 119 - 121) do not exceed 5.1 mm/s peak during the runup. The filtered compensated shaft displacement levels measured at the bearings (Figures 122 - 125) do not exceed 55 μm p-p.

Peaks in the inboard bearing casing response close to 18 Hz (1080 rpm, Figures 120 - 121), at 38 Hz (2280 rpm, Figure 121), at 41 Hz (2460 rpm, Figure 121) and close to 61 Hz (3660 rpm, Figure 119) are due to the presence of structural natural frequencies (identified from impact tests). Compliance transfer functions obtained on the power turbine inboard bearing pedestal in the vertical and axial directions (Figures 185 and 186) show structural natural frequencies at 17.5 Hz, 39.5 Hz, 43.5 Hz and 64 Hz.

RPM spectral maps of the bearing casing velocities and shaft displacements (uncompensated) obtained during the hot start runup are shown in Figures 136 - 142 (Table 7).

3.5 Rundown From Overspeed

Bode plots (filtered 1 x RPM) and RPM spectral maps of the casing velocities and shaft displacements measured on the AC generator and power turbine during the rundown from overspeed (3900 rpm approximately), are discussed in the following subsections. The rundown from overspeed follows the hot start and incremental load changes (Section 2.2 Item 4).

Compensated and uncompensated bode plots are shown for the shaft displacement signals. The slow roll vector at approximately 500 rpm is used for compensation.

3.5.1 AC Generator - Rundown From Overspeed

Figures 143 - 152 (Table 6) show the 1 x RPM filtered bode plots of the AC generator casing velocities and shaft displacements obtained during the rundown.

The filtered (1 x RPM) velocity levels measured on the bearing casings (Figures 143 - 148) do not exceed 0.9 mm/s peak during the rundown. The filtered compensated shaft displacement levels measured at the bearings (Figures 149 - 152) do not exceed 38 μm p-p.

The bode plots (X and Y directions) show a first rotor critical speed at 1410 rpm (23.5 Hz). Amplification factors for the first critical, calculated from the four shaft displacement bode plots obtained on rundown, range from 4.7 to 5.4 and are considered acceptable. The slight difference in the rotor first critical speed on hot runup (24.7 Hz) versus hot rundown (23.5 Hz) is not unusual for rotors supported in hydrodynamic bearings.

The bode plots (X and Y directions) show a steady decrease in vibration from overspeed to approximately 3600 rpm. A possible explanation for this was given in Section 3.4.1.

RPM spectral maps of the bearing casing velocities and shaft displacements (uncompensated) obtained during the rundown are shown in Figures 160 - 169 (Table 6).

3.5.2 Power Turbine - Rundown From Overspeed

Figures 153 - 159 (Table 7) show the 1 x RPM filtered bode plots of the power turbine velocity and displacement levels during the rundown.

The filtered (1 x RPM) velocity levels measured on the inboard bearing casing in the three directions (X, Y and Axial; Figures 153 - 155) do not exceed 3.6 mm/s peak during the rundown. The filtered compensated shaft displacement levels measured at the bearings (Figures 156 - 159) do not exceed 65 μm p-p.

A structural natural frequency close to the synchronous speed is evident in Figure 153.

RPM spectral maps of the bearing casing velocities and shaft displacements (uncompensated) during the rundown are shown in Figures 170 - 176 (Table 7).

3.6 Structural Natural Frequencies

3.6.1 AC Generator - Structural Natural Frequencies

Compliance transfer function spectra obtained on the AC generator outboard and inboard bearing casings are shown in Figures 177 - 182. These impact spectra show no structural natural frequencies close to the synchronous speed (60 Hz) or to twice the synchronous speed.

An impact spectrum obtained on the generator frame in the horizontal direction (Figure 183) shows a structural natural frequency at 66.5 Hz. This structural natural frequency is sufficiently removed from the operating speed (60 Hz) and is not likely to cause any significant vibration amplification.

3.6.2 Power Turbine - Structural Natural Frequencies

Compliance transfer function spectra obtained on the power turbine structure and skid are shown in Figures 184 - 188. Impact spectra obtained on the power turbine inboard bearing pedestal in the horizontal and vertical directions (Figures 184 and 185) show structural natural frequencies at 59 Hz and 64 Hz. Impact spectra obtained on the power turbine skid (Figures 187 - 188) also show structural natural frequencies close to the synchronous speed (60 Hz). No structural natural frequencies appear to be close to 2 x synchronous speed.

Structural natural frequencies close to synchronous speed are considered unacceptable since they can amplify the casing response significantly, unless the mode is well damped.

The 60 Hz component of the power turbine velocities measured on the inboard bearing casing in the X and Y directions (Table 3) is considered acceptable. However, the vibration amplitude at 60 Hz is dependent on the level of excitation at this frequency. Should this excitation increase in the future (most likely due to increased unbalance), amplification of the casing response by the structural natural frequency may result in unacceptable levels of vibration.

3.7 Rotor Natural Frequencies / Critical Speeds

The first rotor critical speed of the AC generator - power turbine unit, identified during runup and rundown, lies approximately between 1410 rpm (23.5 Hz) and 1540 rpm (25.6 Hz).

No other rotor critical speeds within the speed range from zero to overspeed were positively identified from the runup and rundown tests. However, steadily increasing radial vibration levels from approximately 3600 rpm to overspeed (3900 rpm) were noted on the AC generator on runup (Section 3.4.1). The rundown bode plots showed a similar response (Section 3.5.1). A possible rotor natural frequency just above 65 Hz (3900 rpm) is one explanation for this type of response.

In addition, a peak in the outboard bearing casing response (X and Y directions) between 3100 rpm (51.6 Hz) and 3350 rpm (55.8 Hz) was noted on runup (Figures 109 and 110) and rundown (Figures 143 and 144) of the AC generator. The bode plot of the AC generator shaft displacement at the inboard bearing during rundown (Figure 151) also shows a small peak in the response close to 3000 rpm.

Figures 190 and 191 show the AC generator outboard bearing casing (Y-direction) velocity spectrum and outboard shaft displacement (Y - direction) spectrum, respectively, while the unit was operating at a load of 26 MW. Both spectra show broad spectral bands centred at 52 Hz and at approximately 68.5 Hz to 69.5 Hz. These bands are low level responses to a low broad band frequency excitation, and usually indicate the presence of system natural frequencies. A velocity spectrum obtained on the power turbine inboard casing in the X - direction (Figure 192) show similar low level responses at 53 Hz and 68 Hz. Structural impact testing on both the AC generator and power turbine did not reveal structural natural frequencies close to 52 Hz and 68 Hz. In view of this, it is recommended that a theoretical rotor critical speed analysis of the AC generator - power turbine unit be carried out to determine whether these frequencies are rotor natural frequencies. If rotor natural frequencies are shifted (for example, due to changes in bearing clearances) closer to the operating speed, the turbine-generator response would be amplified. Typically, rotor natural frequencies for flexible-shaft rotor systems should be at least 15 percent below or 20 percent above the operating speed unless it can be demonstrated that the vibration response is sufficiently well-damped and insensitive to minor variations in operating or equipment condition.

4.0 CONCLUSIONS

4.1 The overall shaft displacement and bearing casing velocity levels measured on the AC generator, at the five load conditions tested (ranging from 0 MW to 26 MW), are considered acceptable.

4.2 The overall bearing casing velocities measured on the power turbine are considered acceptable. The power turbine overall shaft displacements measured at the outboard bearing are considered acceptable. The maximum overall shaft displacement level measured at the inboard bearing exceeds the acceptance limit of 60 μm p-p by approximately 28 percent.

4.3 A significant 'glitch' is observed on the power turbine shaft at the inboard bearing. This glitch produces a false shaft displacement signal (as measured by the permanently installed displacement transducers). Direct reading instruments used to measure shaft overall levels from these signals would give inaccurate results.

Since the power turbine shaft displacements are not monitored by the on-line vibration monitoring system, the glitch does not present a problem. However, should inboard end shaft displacements be monitored in the future, compensation for the glitch is necessary to obtain accurate overall levels. If feasible, relocating the inboard transducers to a section of the shaft with a 'cleaner' surface could eliminate this problem.

4.4 Structural dynamics testing of the AC generator indicates that all structural natural frequencies are sufficiently removed from the synchronous speed (60 Hz) and twice the synchronous speed.

4.5 Structural dynamics testing of the power turbine shows structural natural frequencies of the power turbine structure/skid (at 58 Hz - 59 Hz and at 62 Hz - 64 Hz) close to the synchronous

speed. Although the velocity levels measured on the power turbine bearing casing are presently acceptable, increased levels of excitation at the synchronous frequency (most likely due to unbalance) combined with the possible amplification of the casing response by the structural natural frequencies could result in unacceptable levels of vibration.

4.6 The first rotor critical speed of the AC generator - power turbine unit, identified during runup and rundown, is between 1410 rpm (23.5 Hz) and 1540 rpm (25.6 Hz). Amplification factors while going through the first critical range from 3.4 to 5.4 and are considered acceptable.

4.7 No other rotor critical speeds within the speed range from zero to overspeed were positively identified from the runup and rundown tests. However, there are indications of possible rotor natural frequencies at approximately 52 Hz and 68 Hz. If rotor natural frequencies are shifted (for example, due to changes in bearing clearances) closer to the operating speed, the turbine-generator response would be amplified.

5.0 RECOMMENDATIONS

5.1 It is recommended that velocity spectra be obtained on the power turbine inboard and outboard structures periodically to obtain a trend of the 60 Hz component. If the 60 Hz component increases significantly, remedial action should be undertaken. Detuning the structural natural frequencies close to the operating speed would be one possible solution.

5.2 It is recommended that a theoretical rotor critical speed analysis of the AC generator - power turbine unit be carried out to determine the rotor dynamic characteristics.

Approved:

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REFERENCES

1. N. Jagan, P. Hoogendam, "Darlington NGS 'A' Standby Generator #2 - Vibration Acceptance Tests", Ontario Hydro Research Division Report No. 89-4-K.

2. N. Jagan, P. Hoogendam, "Darlington NGS 'A' Standby Generator #3 - Vibration Acceptance Tests", Ontario Hydro Research Division Report No. 89-5-K.

3. N. Jagan, P. Hoogendam, "Darlington NGS 'A' Standby Generator #4 - Vibration Acceptance Tests", Ontario Hydro Research Division Report No. 89-6-K.

4. "Type H Industrial Combustion Gas Turbines for Refinery Services", API Standard 616, 2nd Ed, June 1982.

TABLE 1
INSTRUMENTATION LIST

1. Accelerometer	Bruel & Kjaer Model 4368
2. Accelerometer	Endevco Model 7707-1000
3. Displacement Transducer	Bently Nevada Model 21505-00-12-60-02
4. Charge Amplifier	Bruel & Kjaer Model 2635
5. Displacement Transducer Amplifier	Ontario Hydro Research
6. Photoelectric Tachometer Probe	Bruel & Kjaer MM 0024
7. Dual Channel Analyzer	Ono Sokki CF 920
8. Digital Plotter	Hewlett-Packard Model 7470A
9. Laserjet Printer	Texas Instruments - Omnilaser 2108
10. Oscilloscope	Tektronix Model 2215
11. Tape Recorder	Honeywell Model 101
12. Filter	Krohn-Hite Model 3343
13. Vibration Calibrator	General Radio Model 1557-A
14. Digital Vector Filter	Bently Nevada DVF 2
15. Instrumented Tip Impact Hammer	PCB Piezotronics Inc, Model 086B50
16. Personal Microcomputer	IBM-PC AT

TABLE 2

DARLINGTON GS 'A' STANDBY GENERATOR #1
AC GENERATOR 1 x SYNCHRONOUS, 2 x SYNCHRONOUS AND OVERALL CASING VELOCITY LEVELS

Load (MW)	AC Generator Outboard Bearing Casing Velocity X - Direction				AC Generator Outboard Bearing Casing Velocity Y - Direction				AC Generator Outboard Bearing Casing Velocity Axial Direction			
	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk
0	0.18	0.32	0.4	0.7	0.08	0.34	0.4	1.0	0.52	0.12	0.4	0.9
7	0.15	0.29	0.5	0.9	0.15	0.36	0.6	1.2	0.58	0.05	0.5	0.9
13	0.13	0.26	0.5	0.9	0.22	0.36	0.6	1.2	0.63	0.06	0.5	0.9-1.1
20	0.13	0.20	0.5	1.0-1.1	0.27	0.32	0.6	1.2-1.3	0.64	0.07	0.5	1.0-1.3
26	0.10	0.16	0.5	1.0-1.2	0.28	0.28	0.6	1.2-1.4	0.56	0.12	0.4-0.5	0.8-1.0

Load (MW)	AC Generator Inboard Bearing Casing Velocity X - Direction				AC Generator Inboard Bearing Casing Velocity Y - Direction				AC Generator Inboard Bearing Casing Velocity Axial Direction			
	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk
0	0.44	0.27	0.5	1.1	0.47	0.45	0.7	1.3	0.30	0.14	0.3	0.7
7	0.41	0.29	0.5	1.1	0.44	0.37	0.7	1.4	0.30	0.09	0.3	0.7
13	0.36	0.34	0.5	1.1	0.38	0.38	0.6-0.7	1.3-1.5	0.30	0.06	0.3	0.7
20	0.32	0.44	0.6	1.2	0.32	0.51	0.8	1.4	0.32	0.04	0.3	0.8
26	0.35	0.49	0.6	1.2-1.3	0.38	0.58	0.8	1.5-1.7	0.28	0.09	0.4	0.8

TABLE 3

DARLINGTON GS 'A' STANDBY GENERATOR #1
POWER TURBINE 1 x SYNCHRONOUS, 2 x SYNCHRONOUS AND OVERALL CASING VELOCITY LEVELS

	Power Turbine Inboard Bearing Casing Velocity X - Direction				Power Turbine Inboard Bearing Casing Velocity Y - Direction				Power Turbine Inboard Bearing Casing Velocity Axial Direction			
Load (MW)	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk
0	1.90	0.07	1.5-2.1	2.8-3.7	2.52	0.13	1.6-2.0	2.7-4.0	0.54	0.15	1.2-1.8	1.9-4.0
7	1.82	0.07	1.4-1.8	2.9-4.2	2.36	0.14	1.6-1.9	3.0-3.9	0.67	0.09	1.4-1.6	1.6-2.8
13	1.95	0.11	1.4-1.7	2.7-3.8	2.33	0.17	1.5-1.8	2.5-3.4	0.73	0.10	1.5-2.1	2.4-3.9
20	2.03	0.20	1.4-1.7	2.7-3.4	2.38	0.16	1.6-1.8	2.7-3.6	0.73	0.14	1.1-1.3	2.4-3.0
26	1.52	0.20	1.2-1.3	2.4-3.3	2.18	0.17	1.5-1.8	2.6-3.9	0.66	0.13	1.1-1.3	2.4-3.2

TABLE 4

DARLINGTON GS 'A' STANDBY GENERATOR #1
AC GENERATOR 1 x SYNCHRONOUS, 2 x SYNCHRONOUS, AND OVERALL SHAFT RELATIVE DISPLACEMENT LEVELS

	AC Generator Outboard Bearing Shaft Displacement X - Direction (um p-p)			AC Generator Outboard Bearing Shaft Displacement Y - Direction (um p-p)			AC Generator Inboard Bearing Shaft Displacement X - Direction (um p-p)			AC Generator Inboard Bearing Shaft Displacement Y - Direction (um p-p)		
Load (MW)	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall
0	23.2	8.3	28	19.8	8.3	27	16.4	1.8	26	19.6	0.8	26
7	22.4	8.3	28	17.9	8.4	26	15.5	1.9	27	18.1	1.1	27
13	21.6	8.4	27	16.5	8.4	25	14.4	2.1	24	16.3	1.4	25
20	20.7	8.3	27	15.1	8.3	24	13.1	2.1	23	14.8	1.6	24
26	19.9	8.2	26	15.8	8.1	23	13.8	2.0	24	15.7	1.8	24

TABLE 5

DARLINGTON GS 'A' STANDBY GENERATOR #1

POWER TURBINE 1 x SYNCHRONOUS, 2 x SYNCHRONOUS, AND OVERALL SHAFT RELATIVE DISPLACEMENT LEVELS

Load (MW)	Power Turbine Inboard Bearing Shaft Displacement X - Direction (μm p-p)					Power Turbine Inboard Bearing Shaft Displacement Y - Direction (μm p-p)					Power Turbine Outboard Bearing Shaft Displacement X - Direction (μm p-p)			Power Turbine Outboard Bearing Shaft Displacement Y - Direction (μm p-p)		
	1 x Sync (60 Hz)		2 x Sync (120 Hz)	Overall		1 x Sync. (60 Hz)		2 x Sync (120 Hz)	Overall		1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall
	Uncompensated	Compensated		Uncorrected	Corrected*	Uncompensated	Compensated		Uncorrected	Corrected*						
0	85.0	14.7	34.3	105 - 130	74	73.1	11.2	36.7	83 - 95	64	4.6	4.7	13 - 21	17.0	7.1	30 - 44
7	84.5	14.4	34.3	114 - 130	77	72.6	10.6	36.8	87 - 96	65	5.2	4.5	13 - 17	17.2	6.9	31 - 42
13	83.1	14.1	34.3	100 - 117	72	70.7	8.5	36.9	85 - 96	65	4.9	4.4	13 - 22	14.5	6.7	25 - 52
20	82.2	13.6	34.2	95 - 107	73	67.8	6.9	37.0	79 - 82	62	4.7	4.3	13 - 18	10.6	6.7	19 - 33
26	89.8	18.2	35.3	97 - 109	73	70.9	9.0	37.0	86 - 88	59	4.8	4.5	13 - 17	8.6	6.6	22 - 30

* Corrected for 'glitch' on shaft

TABLE 6

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR
FIGURE NUMBERS OF VIBRATION SPECTRA, BODE PLOTS AND RPM SPECTRAL MAPS

Measurement		FFT Spectrum Figure No. Load (MW) 0	7	13	20	26	Bode Plot Cold Start Runup Figure No.	Bode Plot Hot Start Runup Figure No.	RPM Spectral Map Hot Start Runup Figure No.	Bode Plot Rundown from Overspeed Figure No.	RPM Spectral Map Rundown from Overspeed Figure No.
Outboard Bearing Casing Velocity	X - Direction	7	13	19	25	31	92	109	126	143	160
	Y - Direction	8	14	20	26	32	93	110	127	144	161
	Axial	9	15	21	27	33	94	111	128	145	162
Inboard Bearing Casing Velocity	X - Direction	10	16	22	28	34	95	112	129	146	163
	Y - Direction	11	17	23	29	35	96	113	130	147	164
	Axial	12	18	24	30	36	97	114	131	148	165
Outboard Bearing Shaft Displacement	X - Direction	52	56	60	64	68	98	115	132	149	166
	Y - Direction	53	57	61	65	69	99	116	133	150	167
Inboard Bearing Shaft Displacement	X - Direction	54	58	62	66	70	100	117	134	151	168
	Y - Direction	55	59	63	67	71	101	118	135	152	169

TABLE 7

DARLINGTON GS 'A' STANDBY GENERATOR #1 - POWER TURBINE
FIGURE NUMBERS OF VIBRATION SPECTRA, BODE PLOTS AND RPM SPECTRAL MAPS

Measurement		FFT Spectrum Figure No. Load (MW) 0	7	13	20	26	Bode Plot Cold Start Runup Figure No.	Bode Plot Hot Start Runup Figure No.	RPM Spectral Map Hot Start Runup Figure No.	Bode Plot Rundown from Overspeed Figure No.	RPM Spectral Map Rundown from Overspeed Figure No.
Inboard Bearing Casing Velocity	X - Direction	37	40	43	46	49	102	119	136	153	170
	Y - Direction	38	41	44	47	50	103	120	137	154	171
	Axial	39	42	45	48	51	104	121	138	155	172
Inboard Bearing Shaft Displacement	X - Direction	72	76	80	84	88	105	122	139	156	173
	Y - Direction	73	77	81	85	89	106	123	140	157	174
Outboard Bearing Shaft Displacement	X - Direction	74	78	82	86	90	107	124	141	158	175
	Y - Direction	75	79	83	87	91	108	125	142	159	176

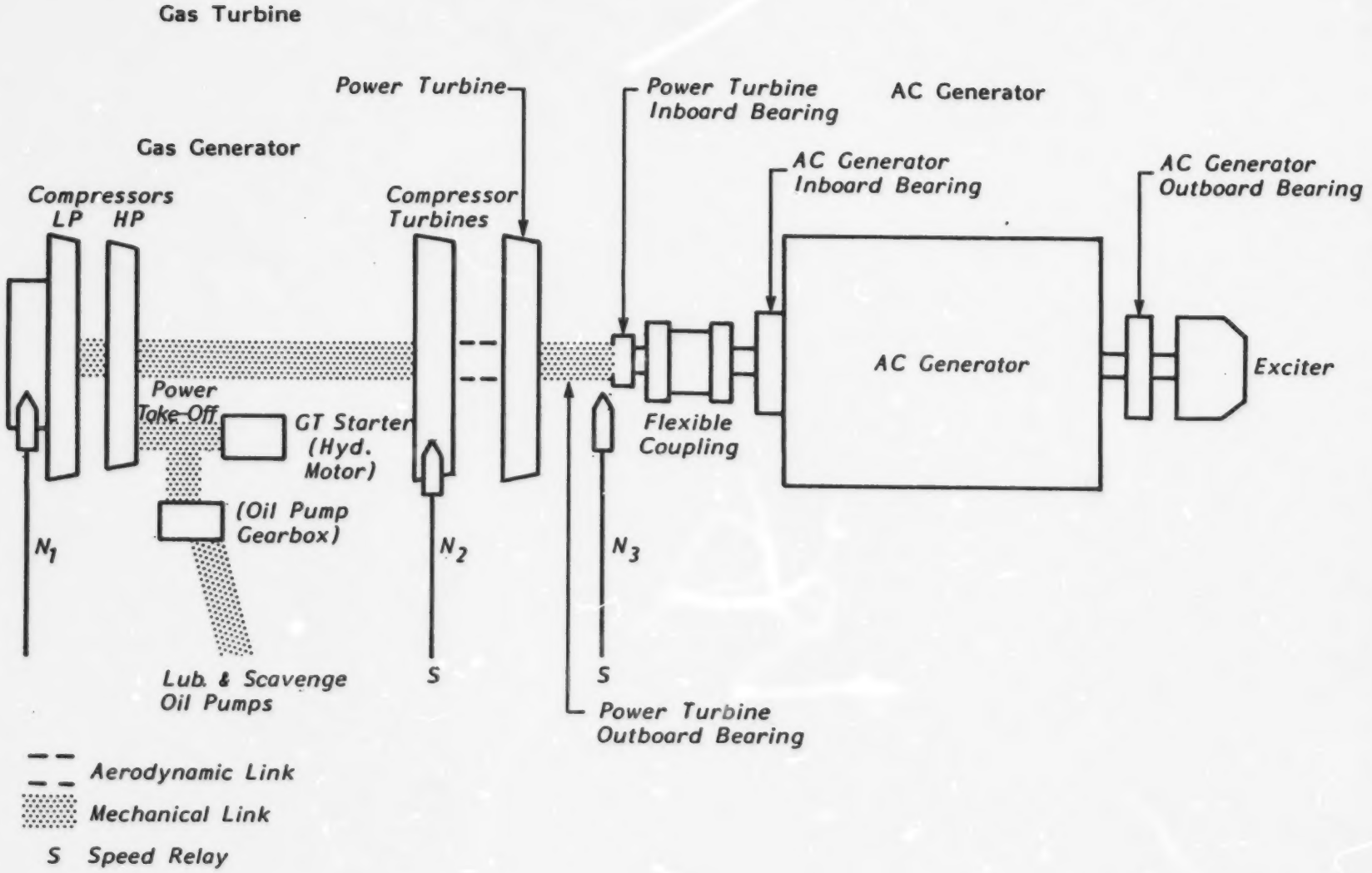


FIGURE 1

DARLINGTON NGS STANDY TURBINE-GENERATOR SYSTEM

177137-RD
88-241

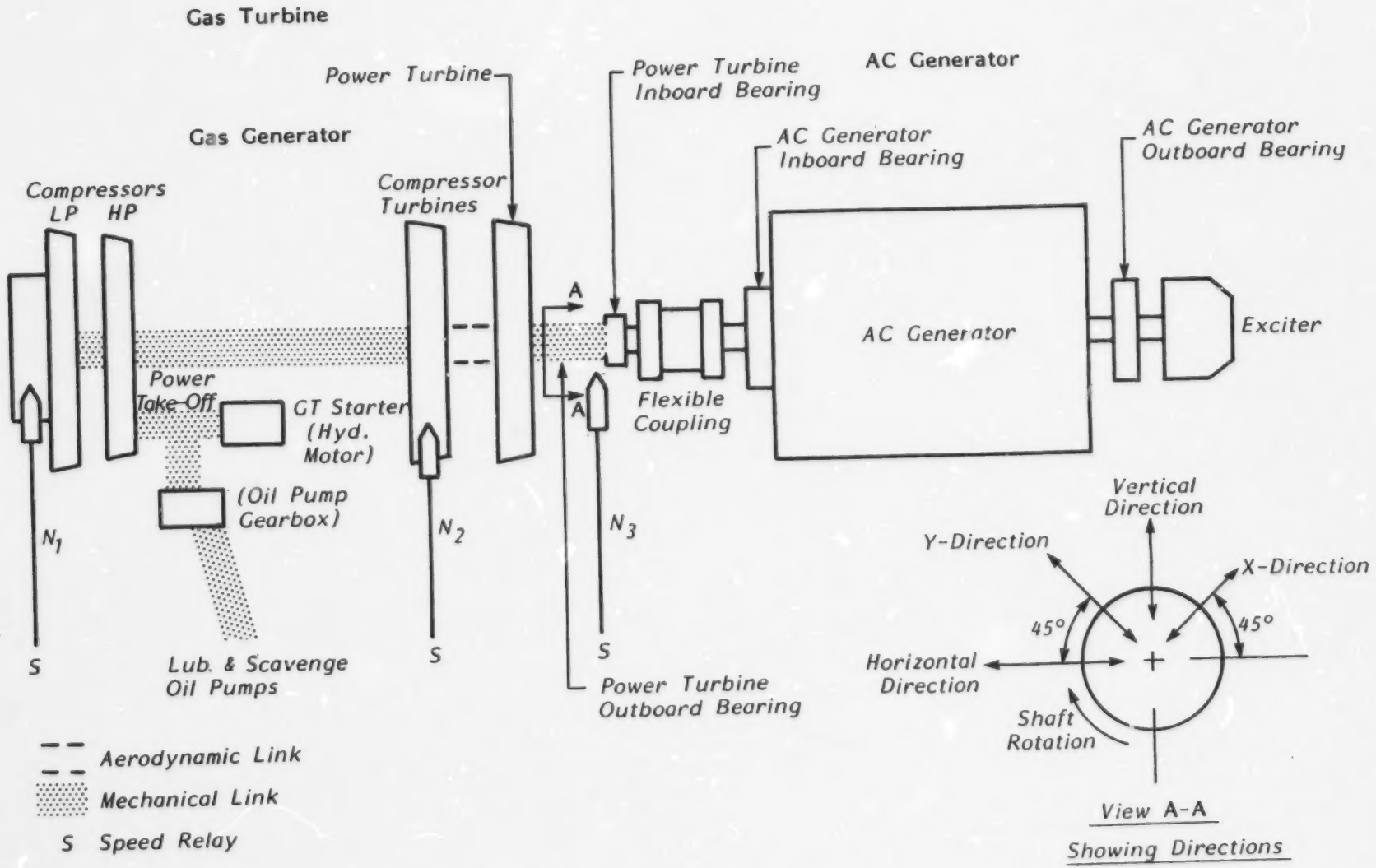
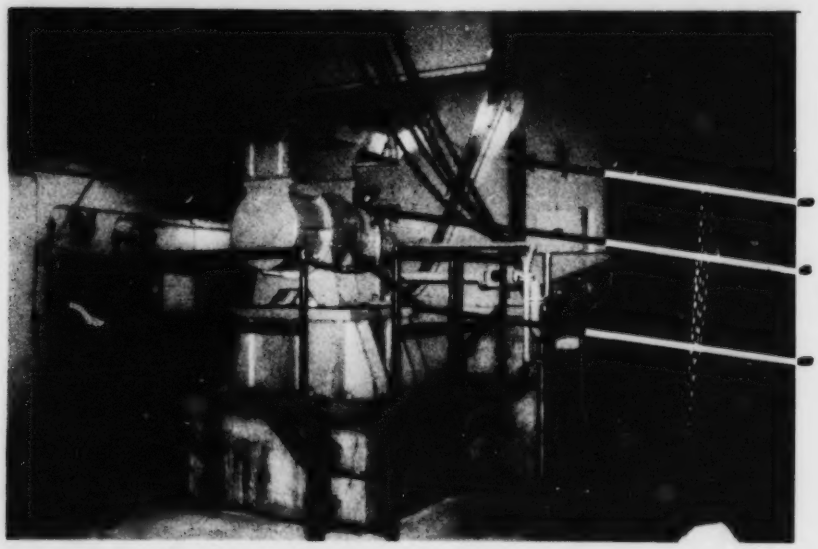


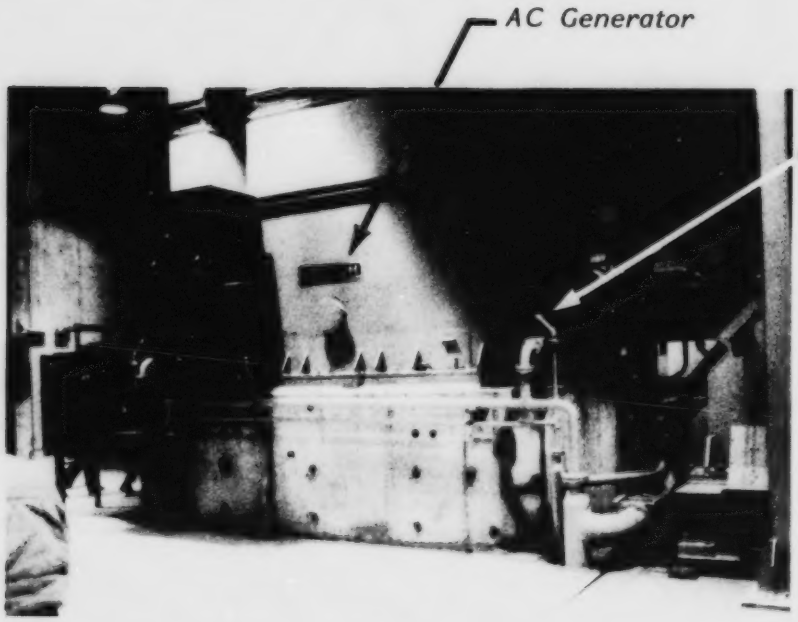
FIGURE 2

DARLINGTON NGS STANDBY TURBINE-GENERATOR SYSTEM
SHOWING MEASUREMENT DIRECTIONS

88-241
177138-RD

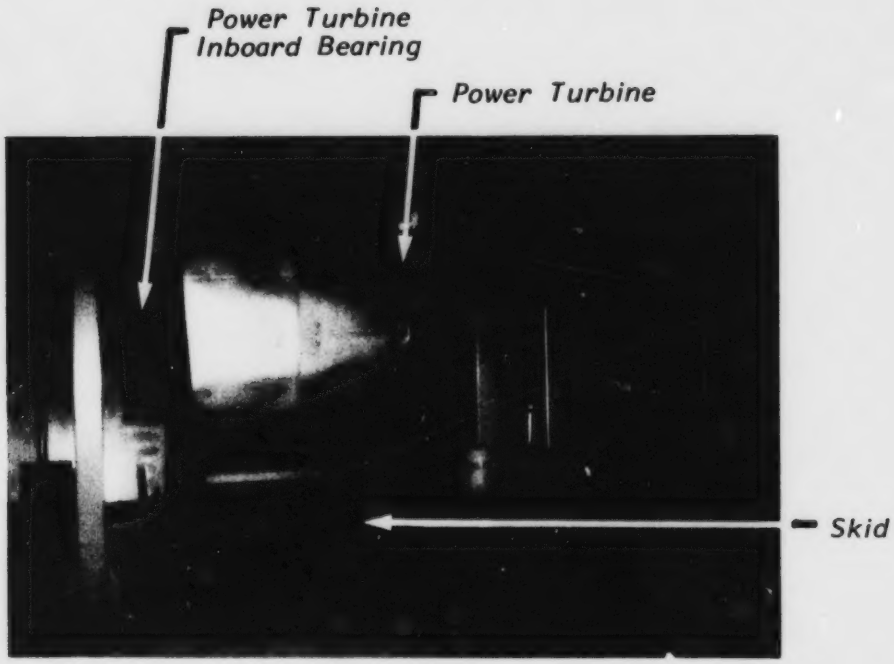


(a)



(b)

FIGURES 3(a) & (b)
LAYOUT OF STANDBY GENERATOR SYSTEM



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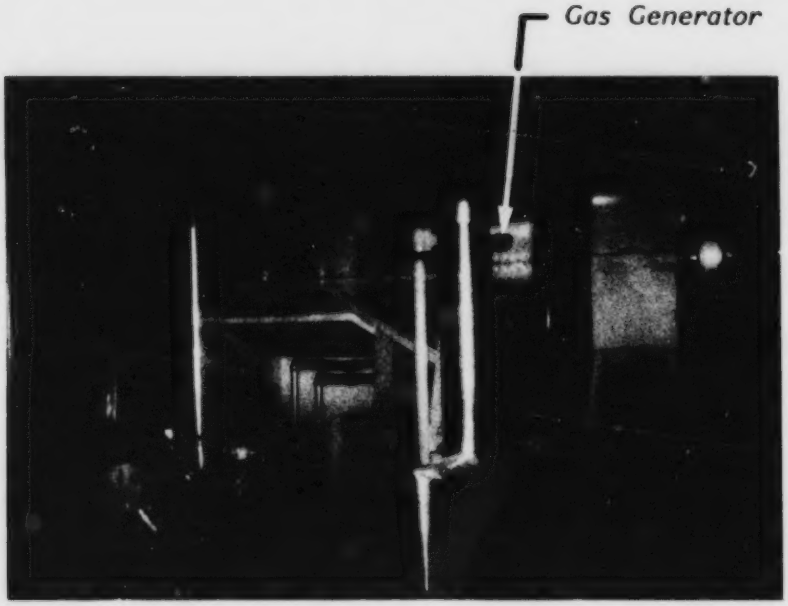
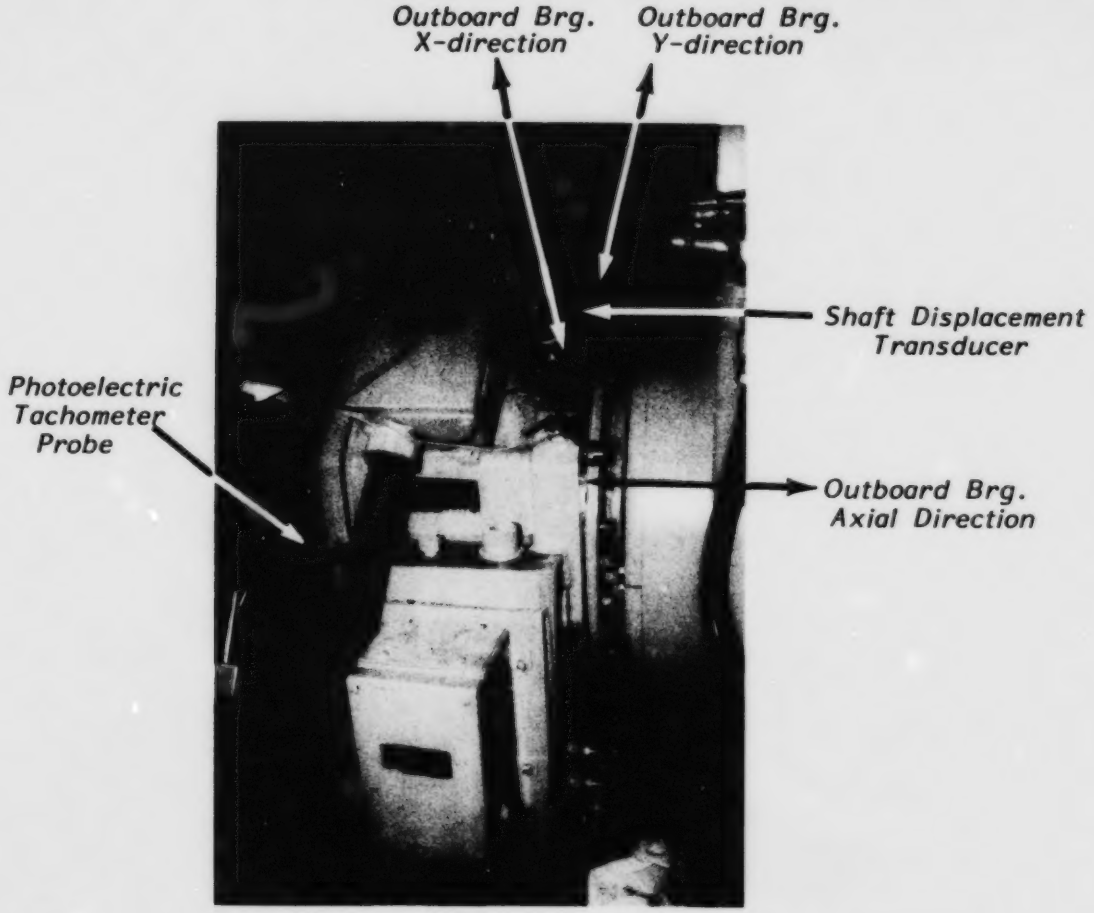
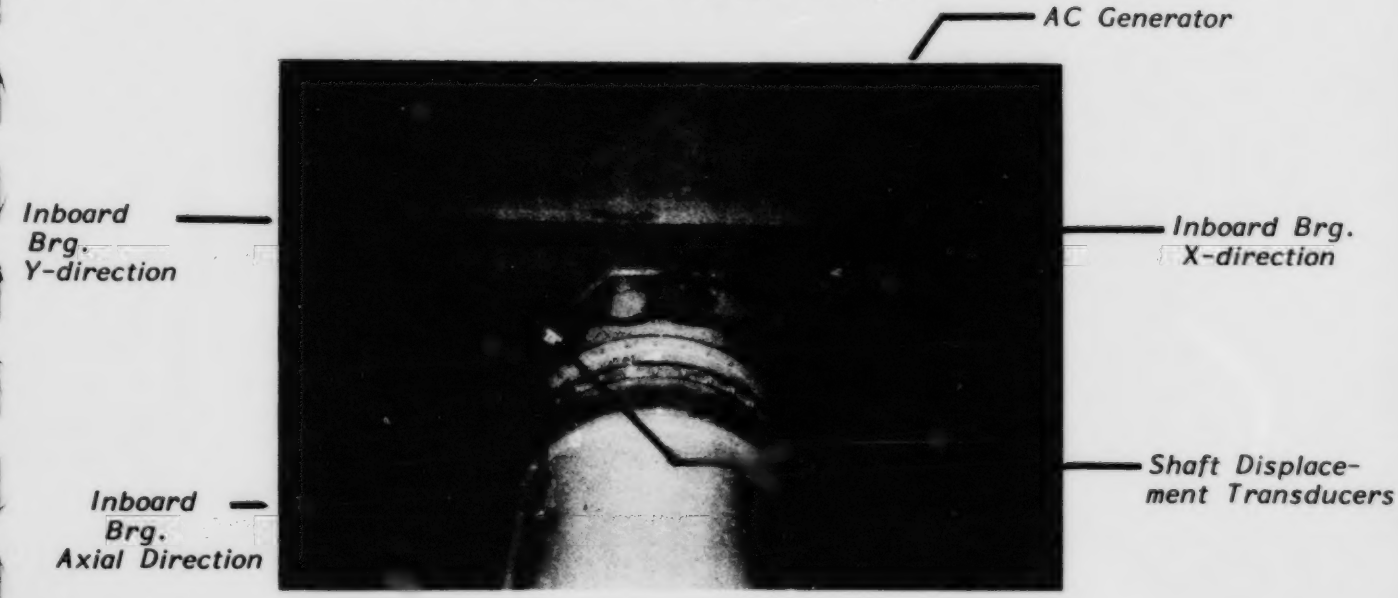


(d)

FIGURES 3(c) & (d)
LAYOUT OF STANDBY GENERATOR SYSTEM



(a) AC Generator Outboard Bearing



(b) AC Generator Inboard Bearing

FIGURE 4

LOCATION AND DIRECTION OF TRANSDUCERS ON AC GENERATOR BEARINGS

177141-RD

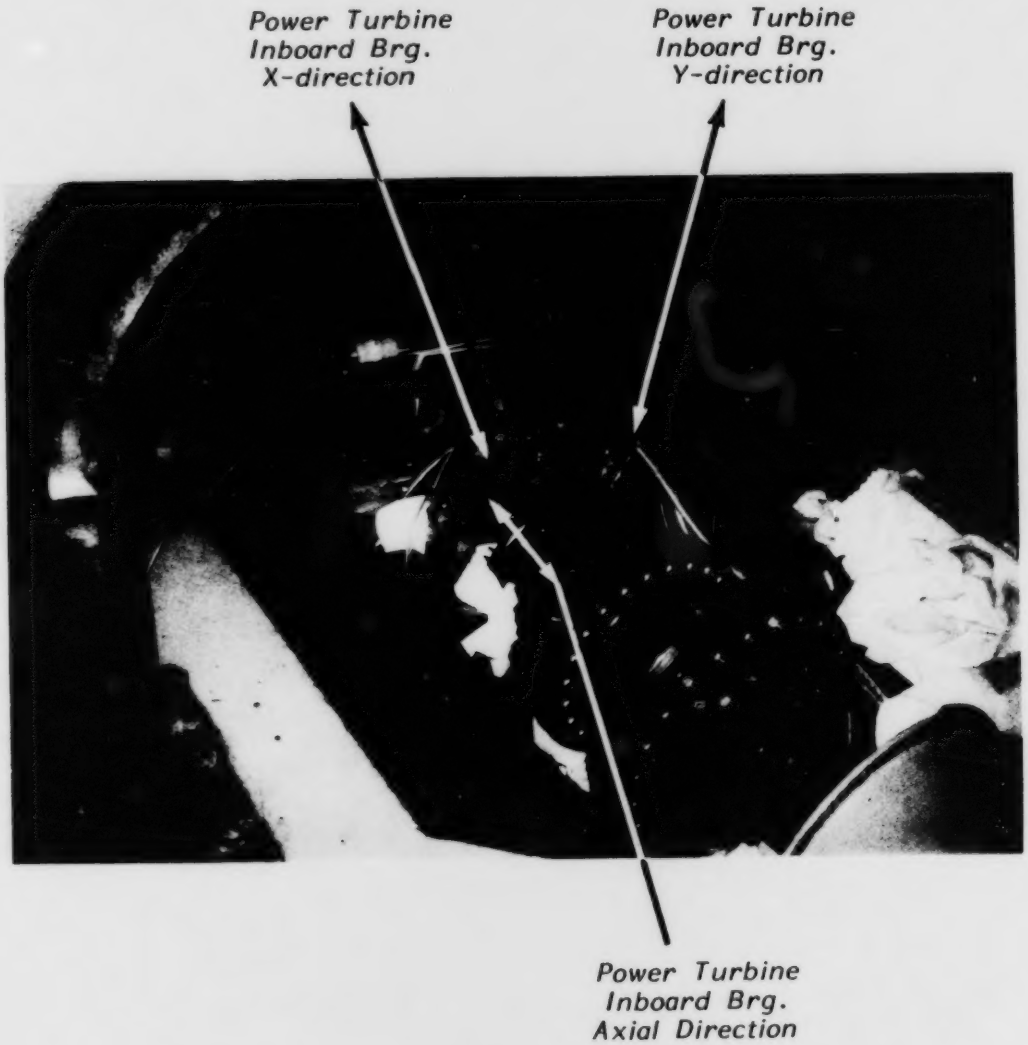


FIGURE 5

POWER TURBINE INBOARD BEARING
MEASUREMENT LOCATIONS

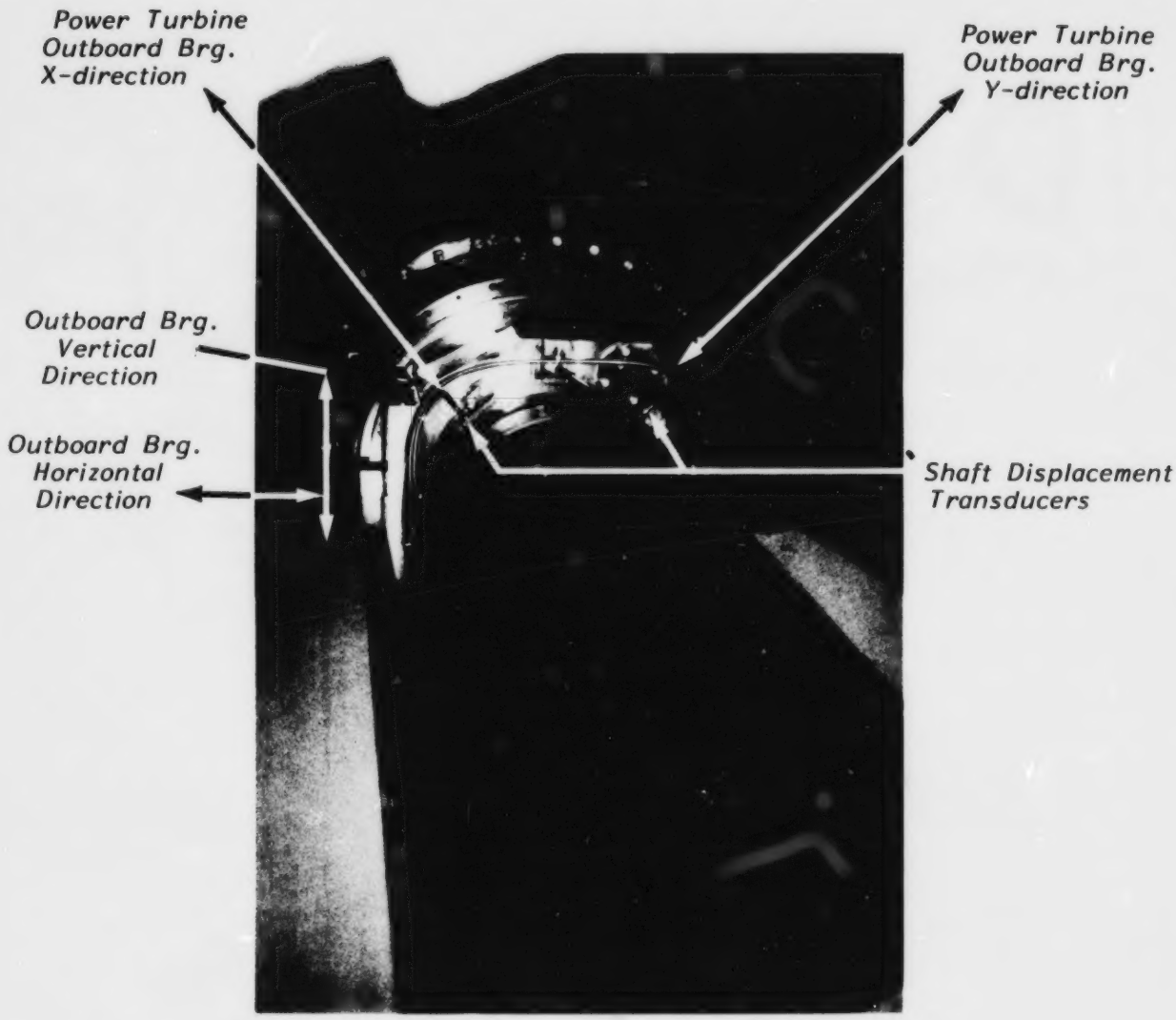


FIGURE 6

POWER TURBINE OUTBOARD BEARING
MEASUREMENT LOCATIONS

177143-RD

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.45
2	120.0	2.00	0.32
3	60.0	1.00	0.18
4	240.0	4.00	0.10
5	19.5	0.33	0.02
6	300.0	5.00	0.02
7	360.0	6.00	0.02
8	174.4	2.91	0.02
9	100.5	1.67	0.02
10	89.3	1.49	0.02

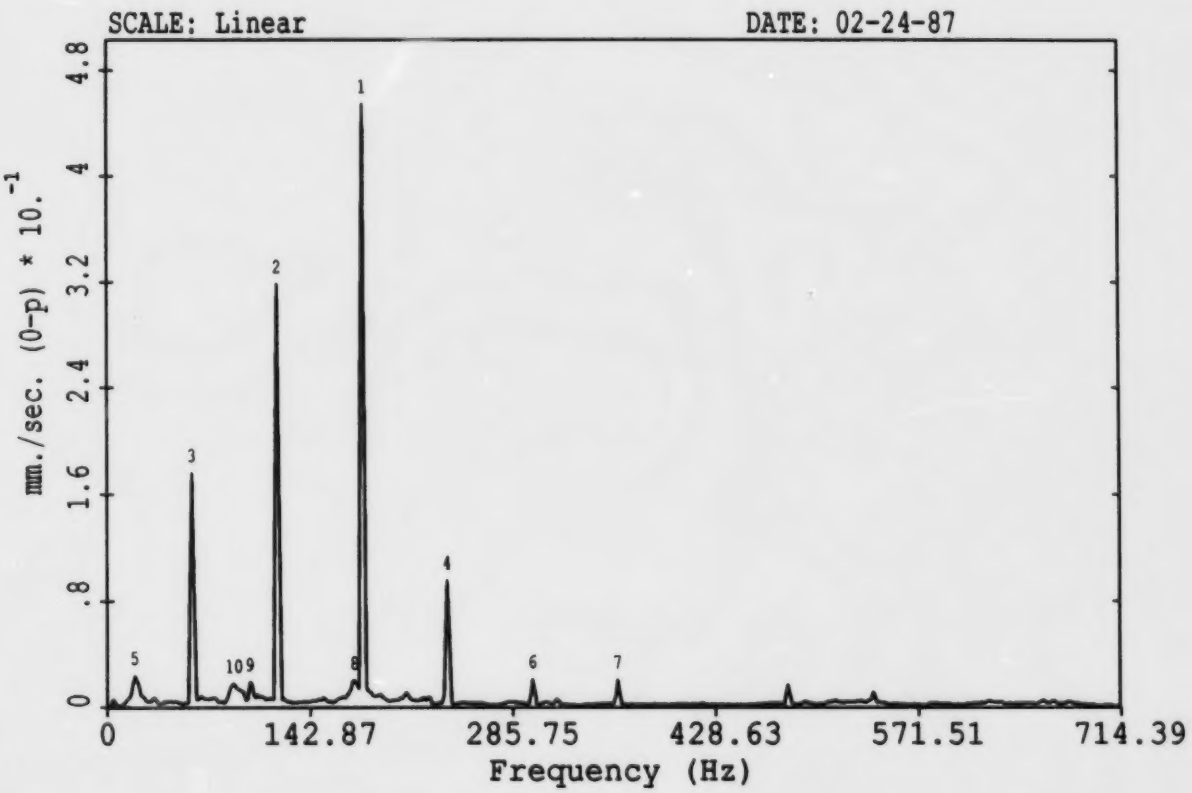


FIGURE 7

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.53
2	120.0	2.00	0.34
3	60.0	1.00	0.08
4	240.0	4.00	0.07
5	360.0	6.00	0.04
6	300.0	5.00	0.03
7	22.3	0.37	0.02
8	87.9	1.47	0.02
9	92.1	1.53	0.02
10	174.4	2.91	0.02

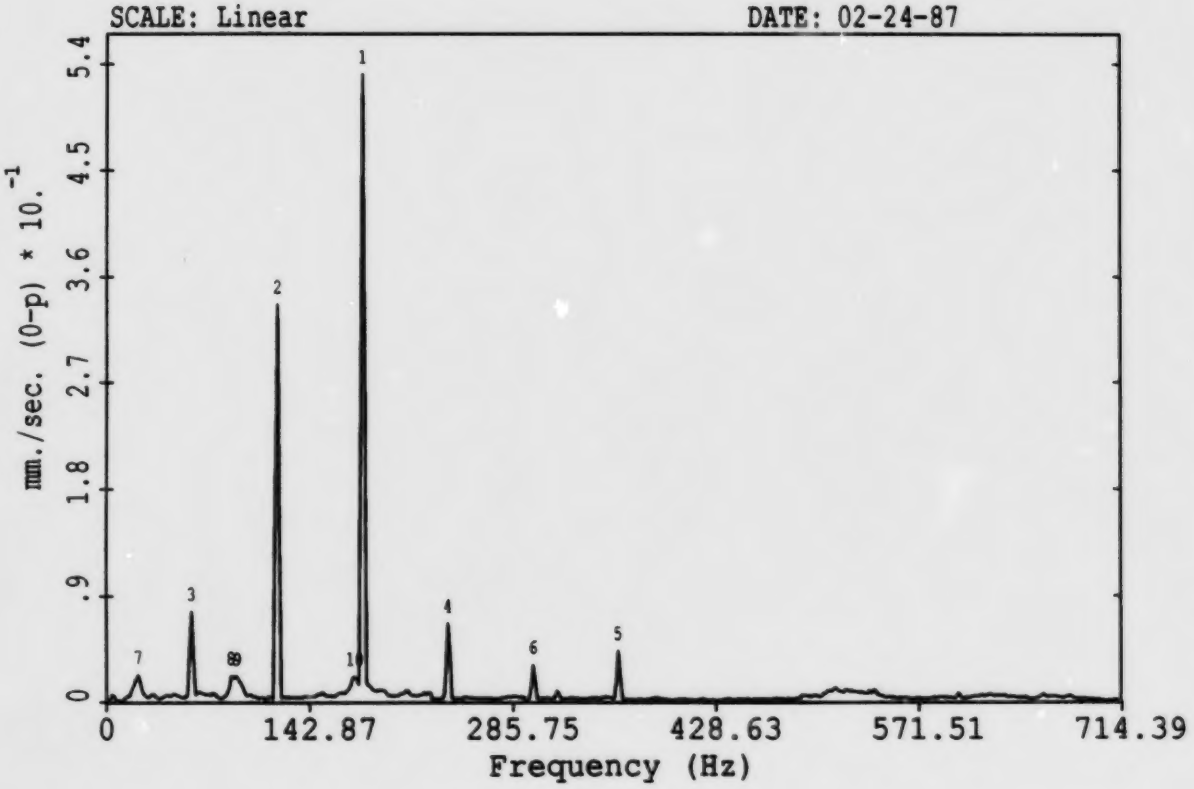


FIGURE 8

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.52
2	87.9	1.47	0.16
3	120.0	2.00	0.12
4	180.0	3.00	0.05
5	96.3	1.60	0.04
6	100.5	1.67	0.04
7	79.5	1.33	0.04
8	104.6	1.74	0.03
9	360.0	6.00	0.03
10	240.0	4.00	0.03

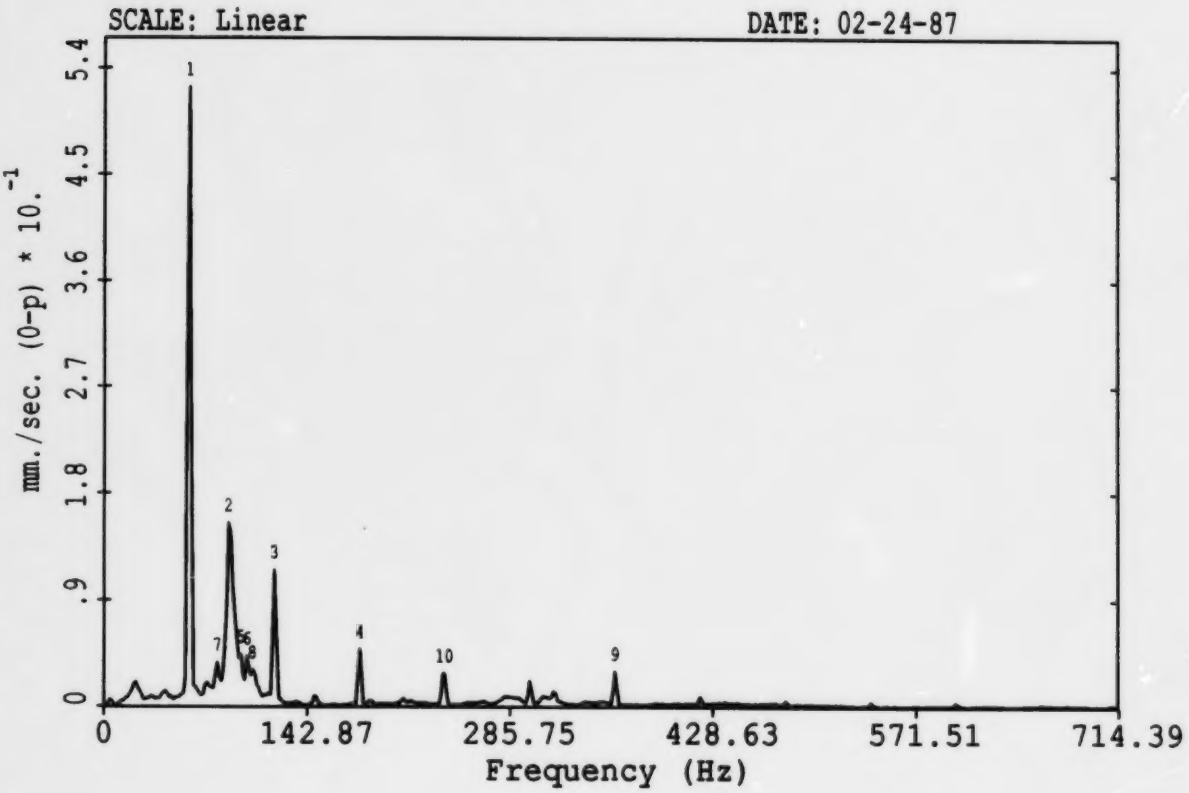


FIGURE 9

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.53
2	60.0	1.00	0.44
3	120.0	2.00	0.27
4	360.0	6.00	0.05
5	240.0	4.00	0.05
6	19.5	0.33	0.03
7	300.0	5.00	0.03
8	22.3	0.37	0.03
9	173.0	2.88	0.03
10	175.8	2.93	0.03

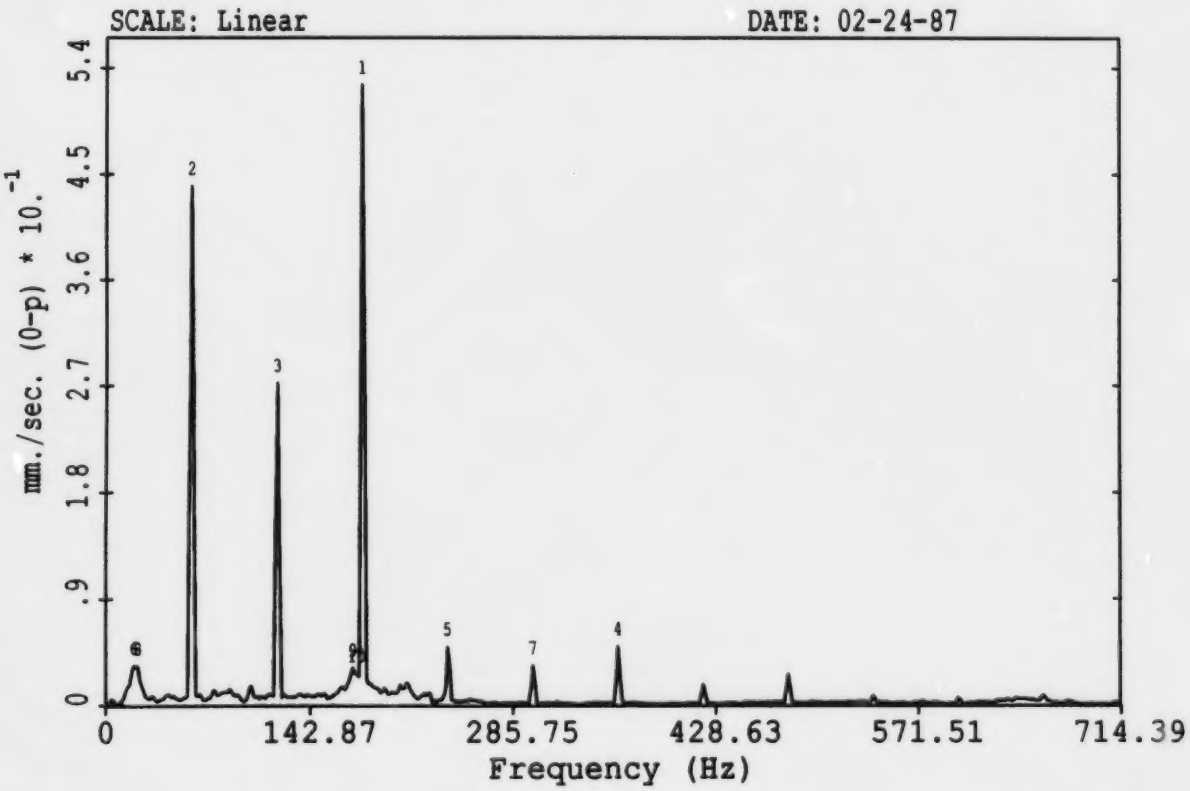


FIGURE 10

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.76
2	60.0	1.00	0.47
3	120.0	2.00	0.45
4	300.0	5.00	0.06
5	240.0	4.00	0.05
6	173.0	2.88	0.04
7	175.8	2.93	0.04
8	210.7	3.51	0.03
9	420.0	7.00	0.03
10	22.3	0.37	0.03

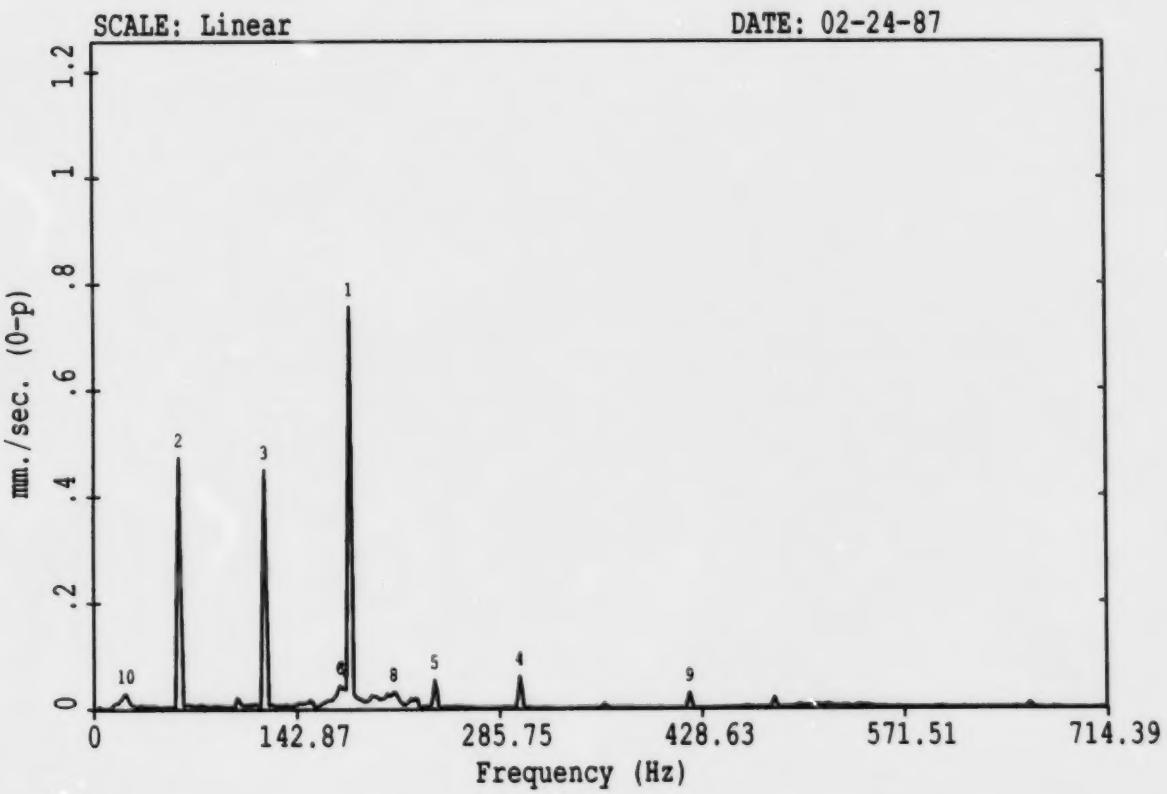


FIGURE 11

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.30
2	180.0	3.00	0.16
3	120.0	2.00	0.14
4	86.5	1.44	0.08
5	240.0	4.00	0.05
6	100.5	1.67	0.04
7	360.0	6.00	0.03
8	76.7	1.28	0.03
9	22.3	0.37	0.02
10	110.2	1.84	0.02

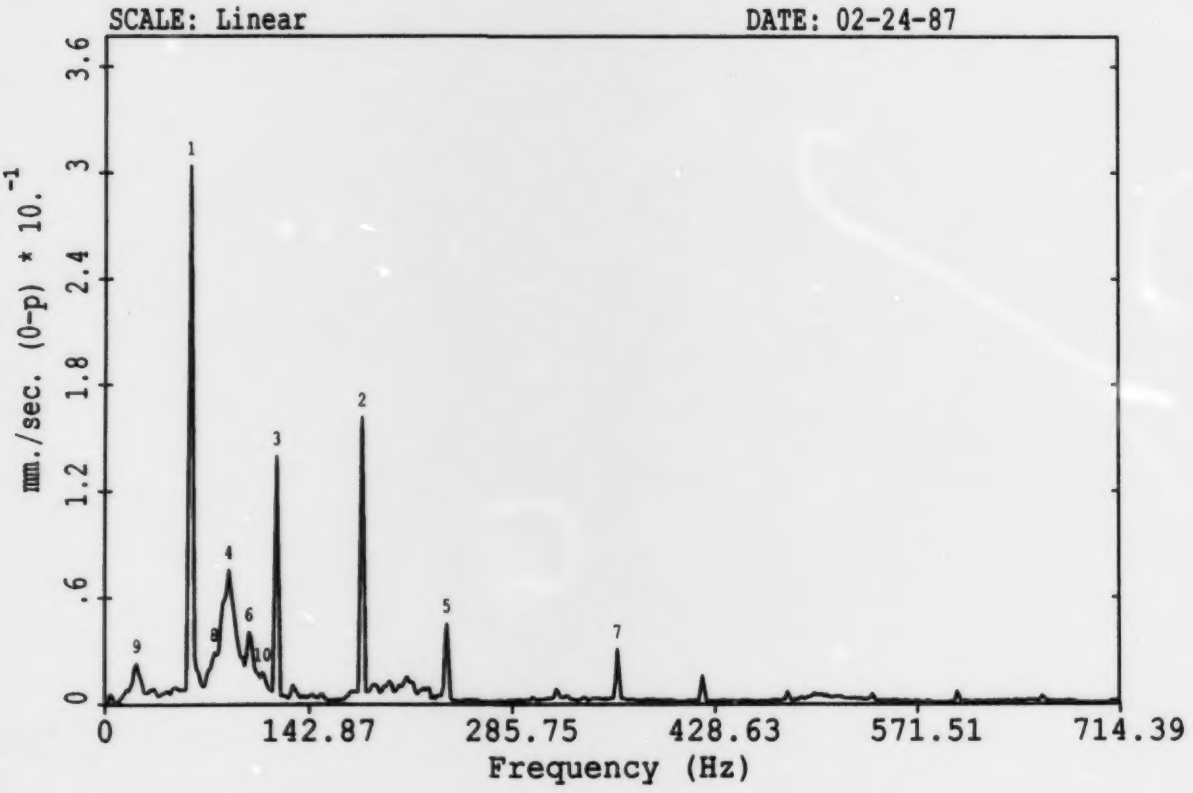


FIGURE 12

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.54
2	120.0	2.00	0.29
3	60.0	1.00	0.15
4	240.0	4.00	0.05
5	170.2	2.84	0.03
6	300.0	5.00	0.02
7	87.9	1.47	0.02
8	174.4	2.91	0.02
9	19.5	0.33	0.02
10	90.7	1.51	0.02

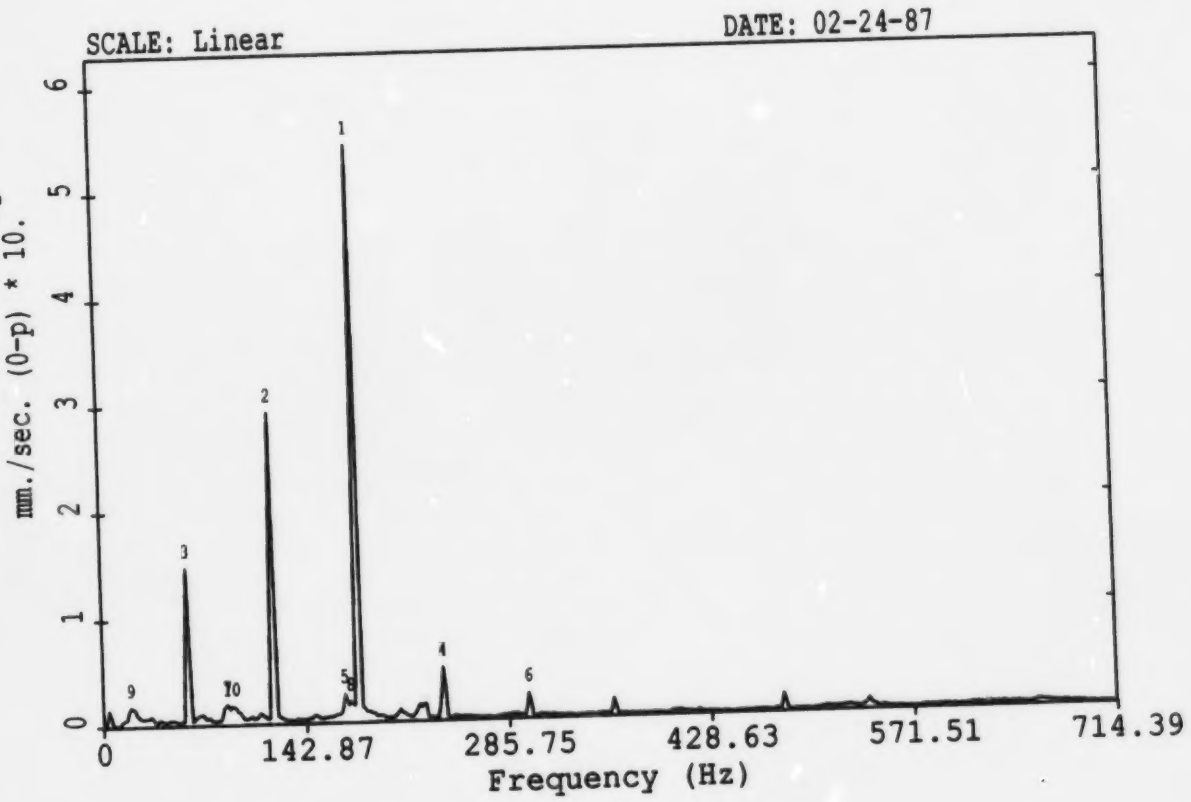


FIGURE 13
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.63
2	120.0	2.00	0.36
3	60.0	1.00	0.15
4	240.0	4.00	0.05
5	360.0	6.00	0.04
6	300.0	5.00	0.03
7	170.2	2.84	0.03
8	89.3	1.49	0.03

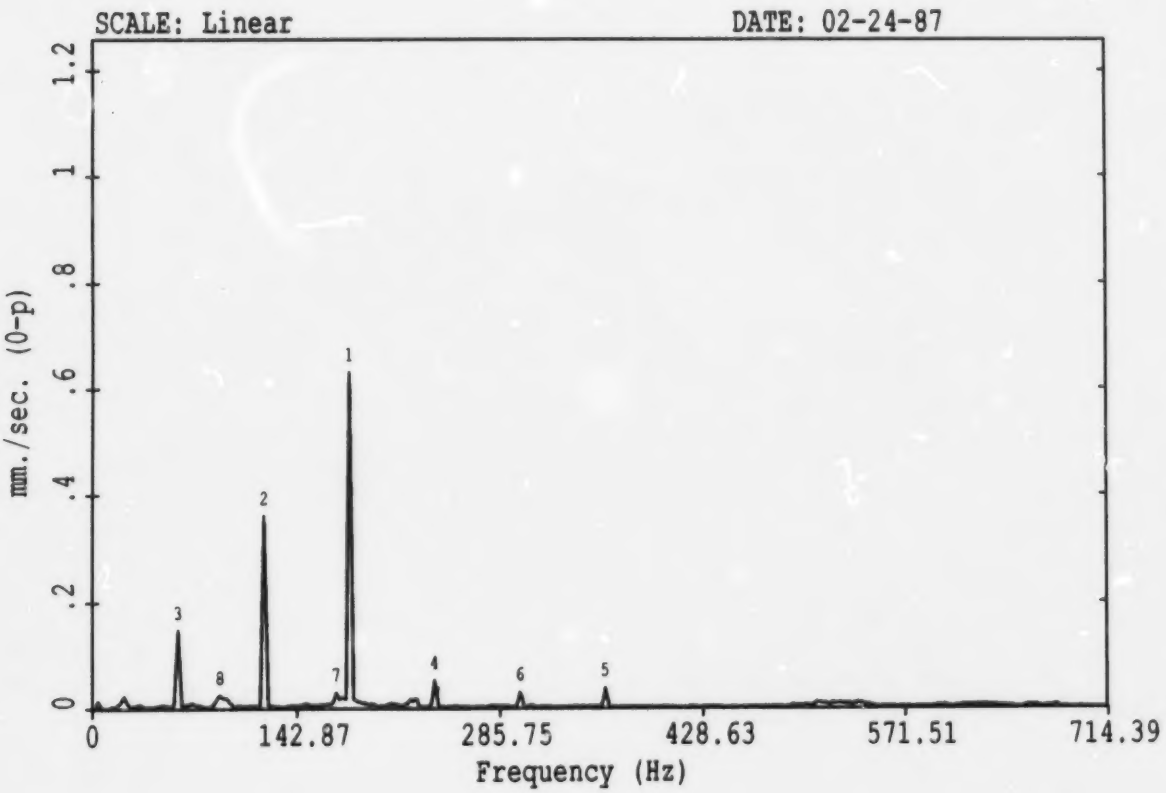


FIGURE 14

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.58
2	87.9	1.47	0.16
3	180.0	3.00	0.06
4	96.3	1.60	0.05
5	120.0	2.00	0.05
6	240.0	4.00	0.04
7	79.5	1.33	0.03
8	360.0	6.00	0.03
9	104.6	1.74	0.03
10	300.0	5.00	0.02

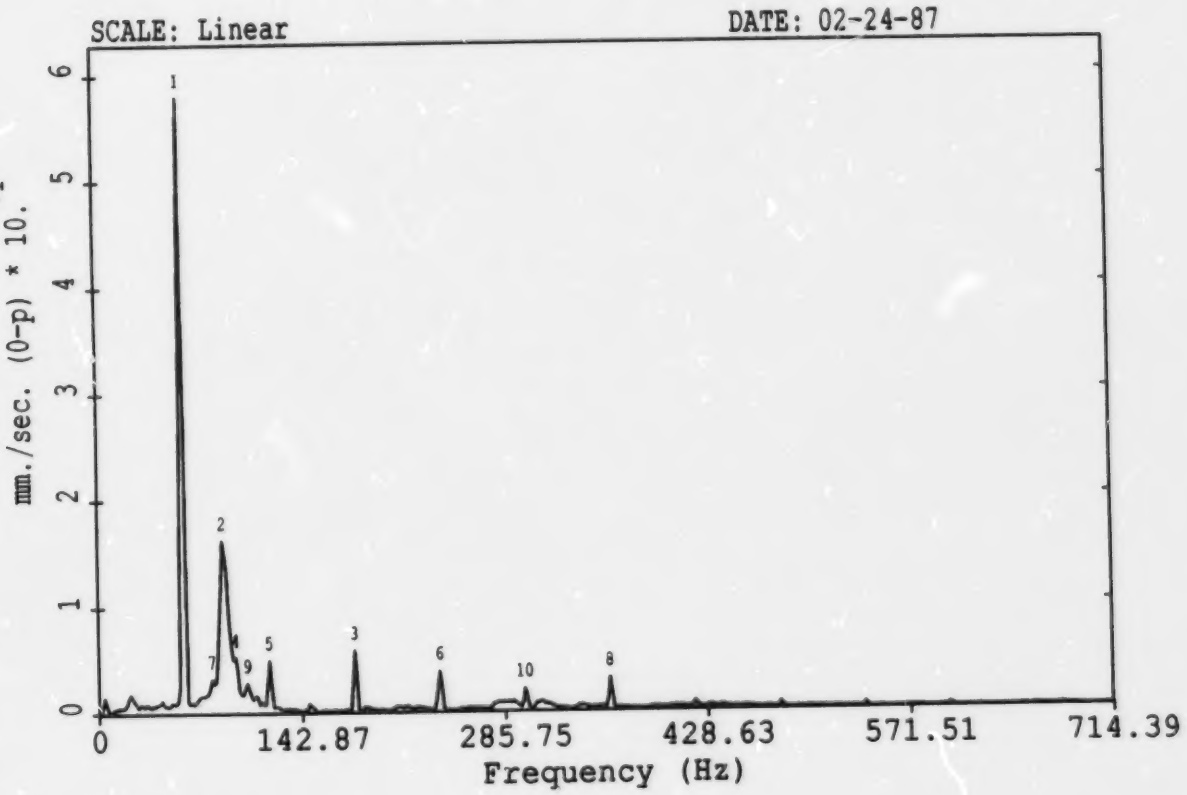


FIGURE 15

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.51
2	60.0	1.00	0.41
3	120.0	2.00	0.29
4	360.0	6.00	0.06
5	170.2	2.84	0.04
6	480.0	8.00	0.04
7	22.3	0.37	0.03
8	174.4	2.91	0.03
9	300.0	5.00	0.03
10	240.0	4.00	0.02

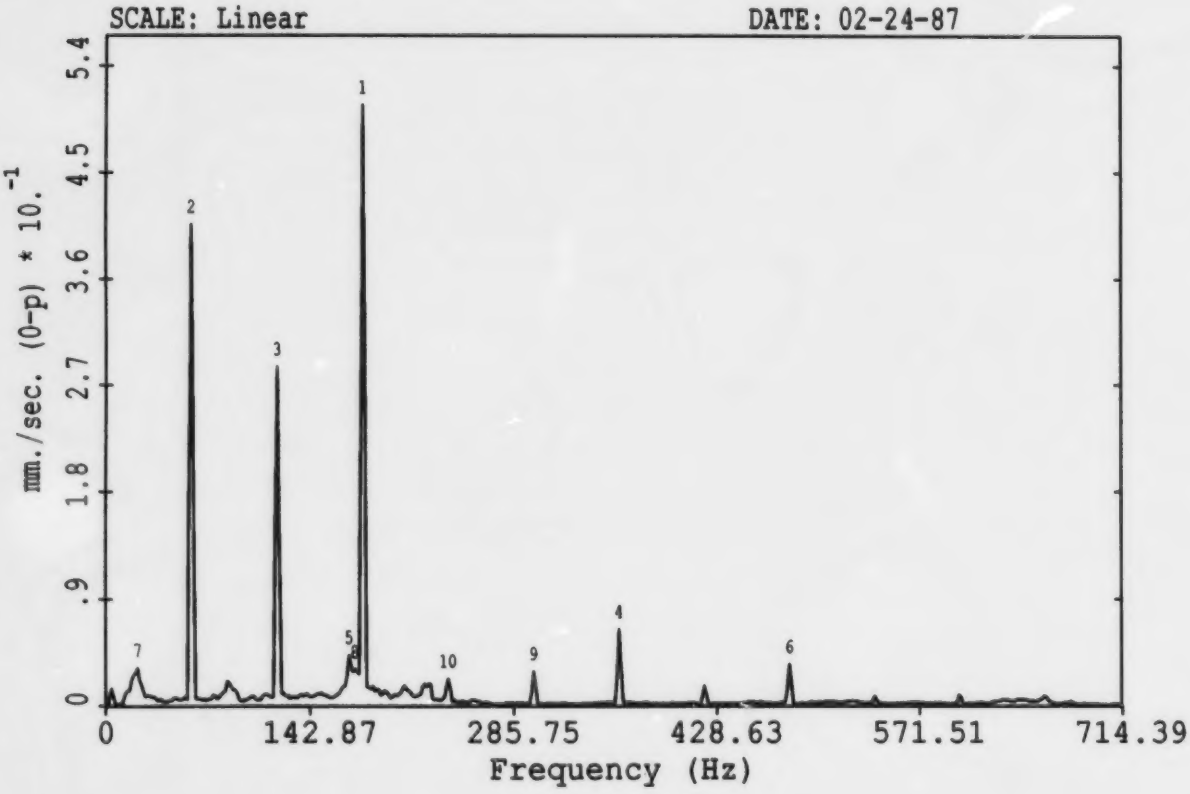


FIGURE 16

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.76
2	60.0	1.00	0.44
3	120.0	2.00	0.37
4	300.0	5.00	0.07
5	170.2	2.84	0.06
6	240.0	4.00	0.05
7	174.4	2.91	0.05
8	223.2	3.72	0.04
9	420.0	7.00	0.03
10	22.3	0.37	0.03

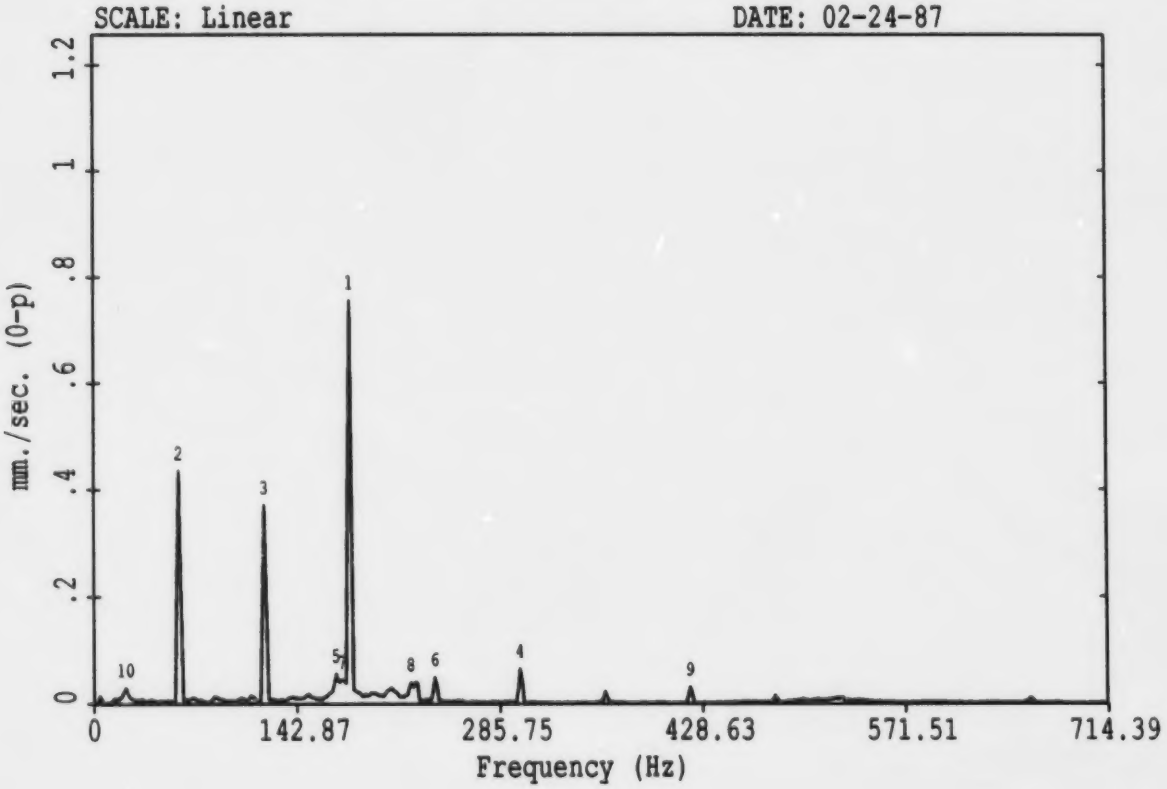


FIGURE 17

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.30
2	180.0	3.00	0.16
3	85.1	1.42	0.12
4	120.0	2.00	0.09
5	96.3	1.60	0.03
6	104.6	1.74	0.03
7	240.0	4.00	0.02
8	22.3	0.37	0.02
9	110.2	1.84	0.02
10	223.2	3.72	0.02

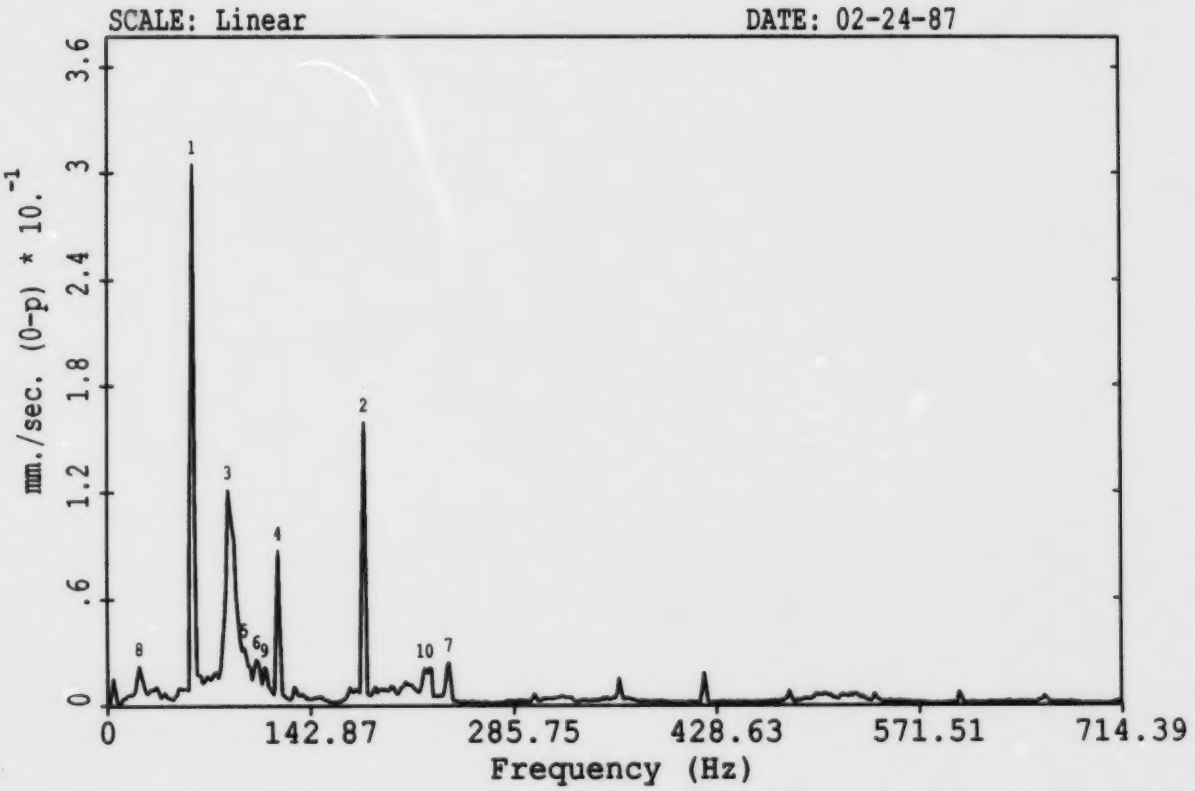


FIGURE 18
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.61
2	120.0	2.00	0.26
3	60.0	1.00	0.13
4	240.0	4.00	0.03
5	185.6	3.09	0.03

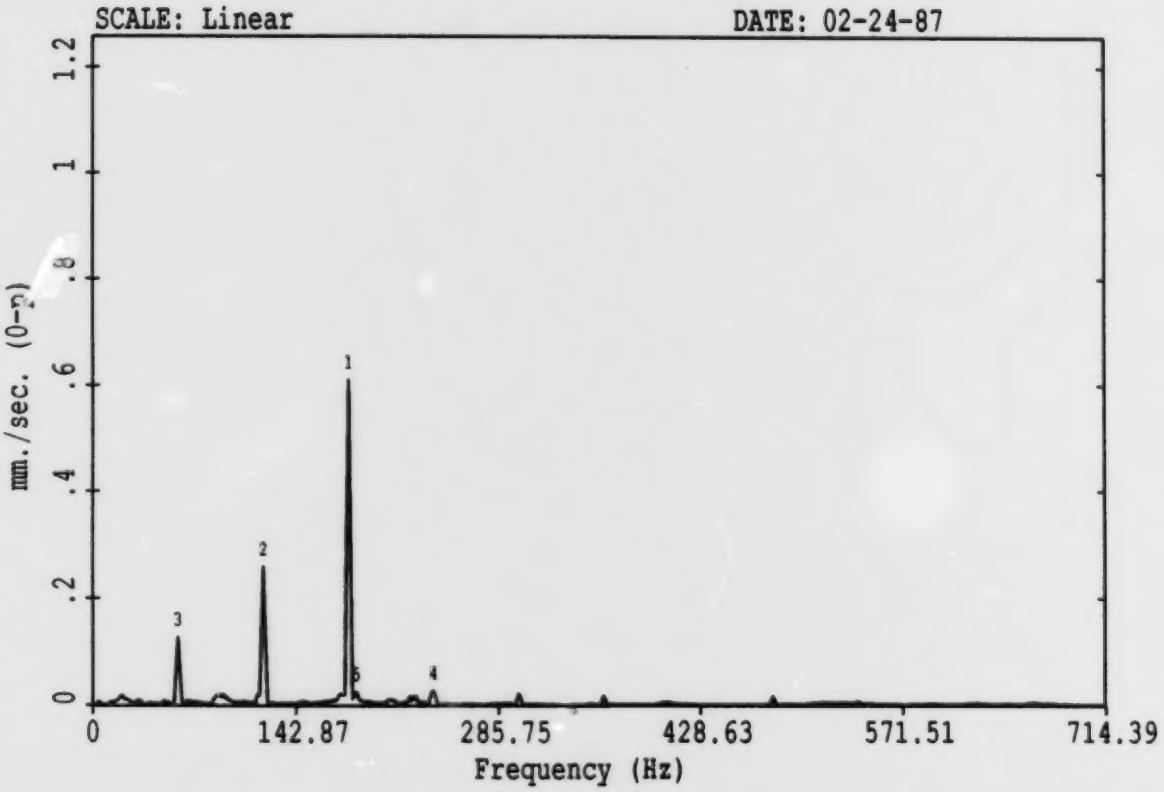


FIGURE 19

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.71
2	120.0	2.00	0.36
3	60.0	1.00	0.22
4	240.0	4.00	0.08
5	300.0	5.00	0.03
6	360.0	6.00	0.03
7	185.6	3.09	0.03
8	90.7	1.51	0.03

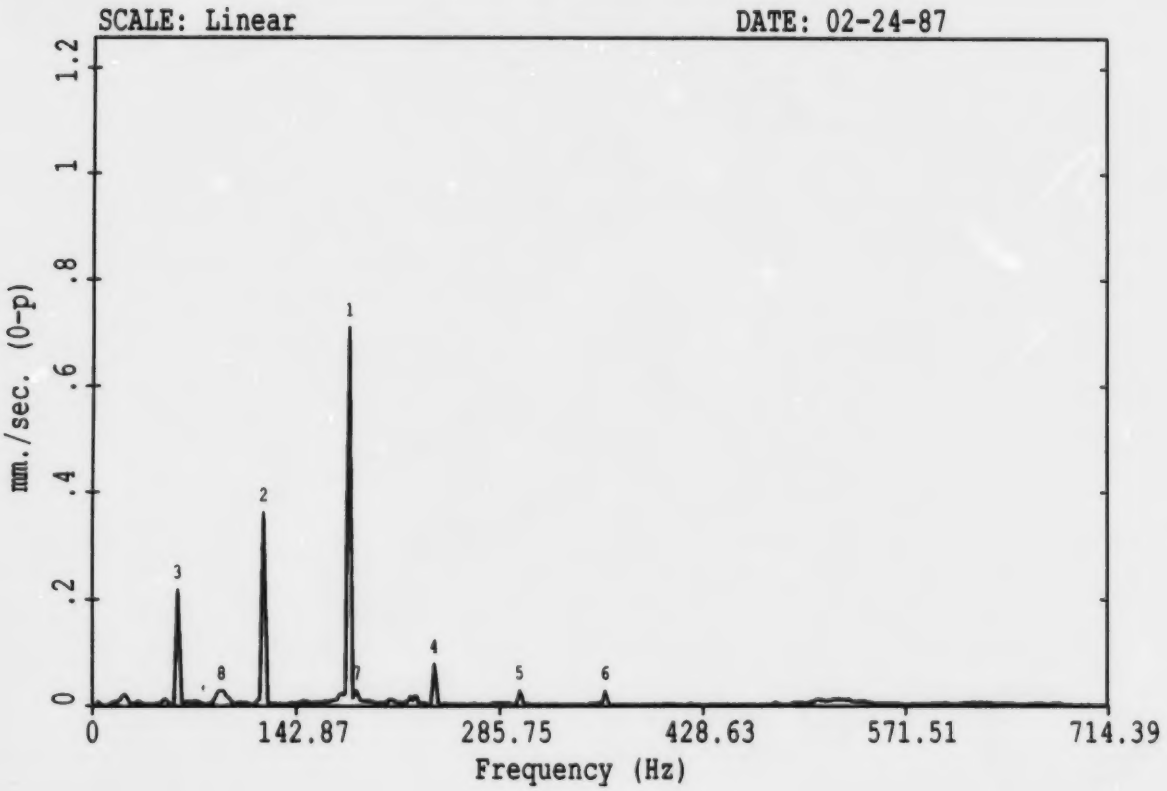


FIGURE 20

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.63
2	87.9	1.47	0.19
3	180.0	3.00	0.06
4	96.3	1.60	0.06
5	120.0	2.00	0.06
6	240.0	4.00	0.05
7	115.8	1.93	0.03
8	104.6	1.74	0.03
9	79.5	1.33	0.03

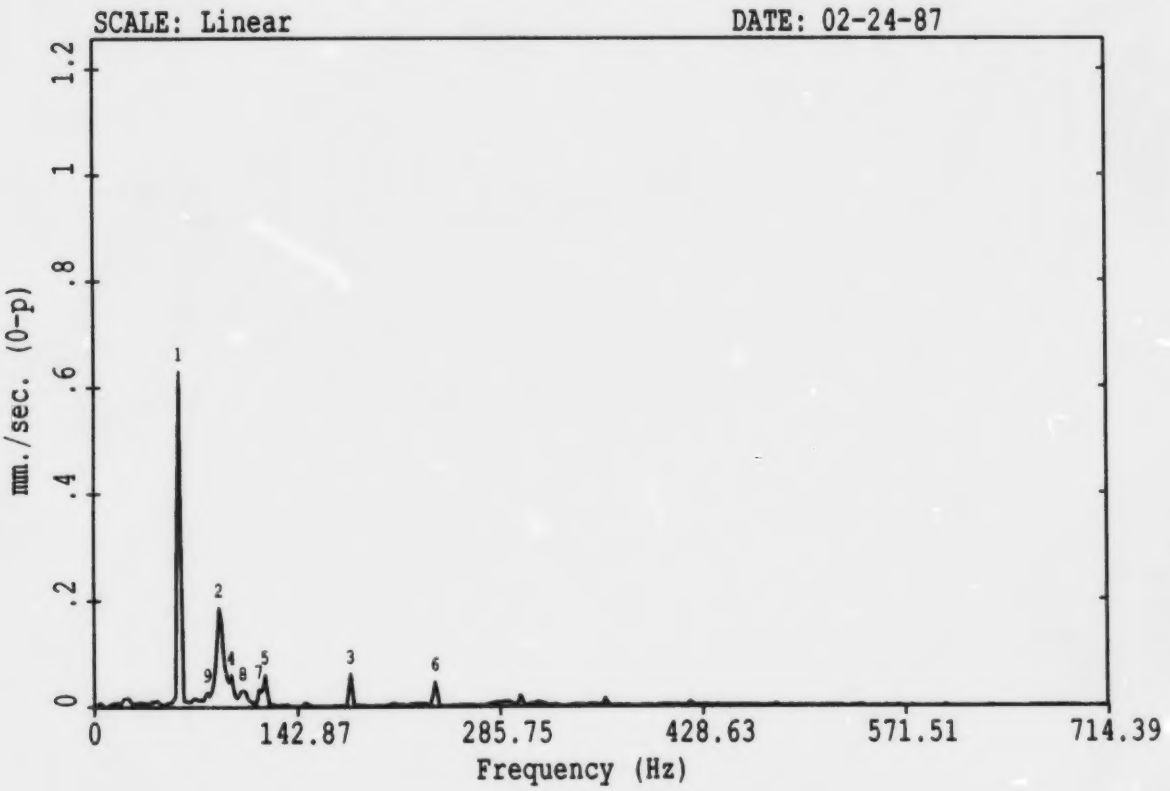


FIGURE 21

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.54
2	60.0	1.00	0.36
3	120.0	2.00	0.34
4	240.0	4.00	0.08
5	360.0	6.00	0.07
6	185.6	3.09	0.04
7	174.4	2.91	0.04
8	480.0	8.00	0.04
9	115.8	1.93	0.03
10	20.9	0.35	0.03

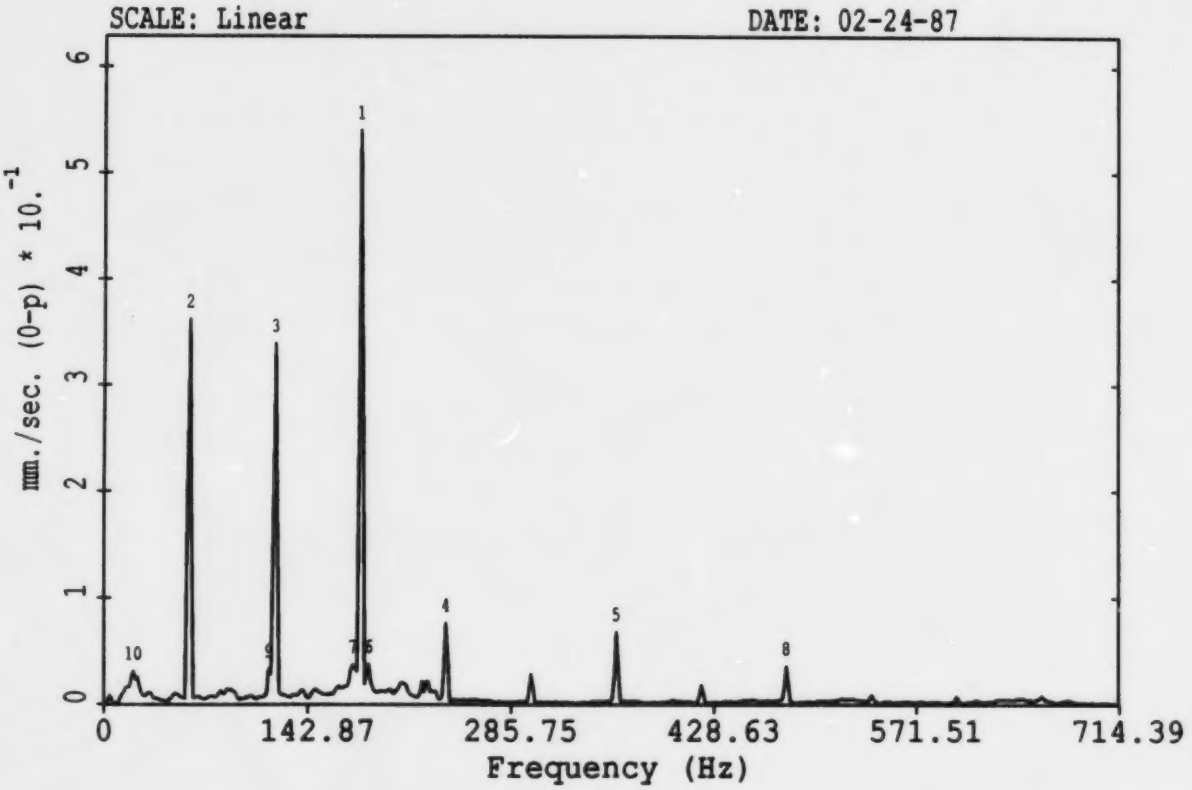


FIGURE 22

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.82
2	120.0	2.00	0.38
3	60.0	1.00	0.38
4	240.0	4.00	0.14
5	300.0	5.00	0.07
6	185.6	3.09	0.05
7	174.4	2.91	0.05
8	223.2	3.72	0.04
9	209.3	3.49	0.04
10	420.0	7.00	0.03

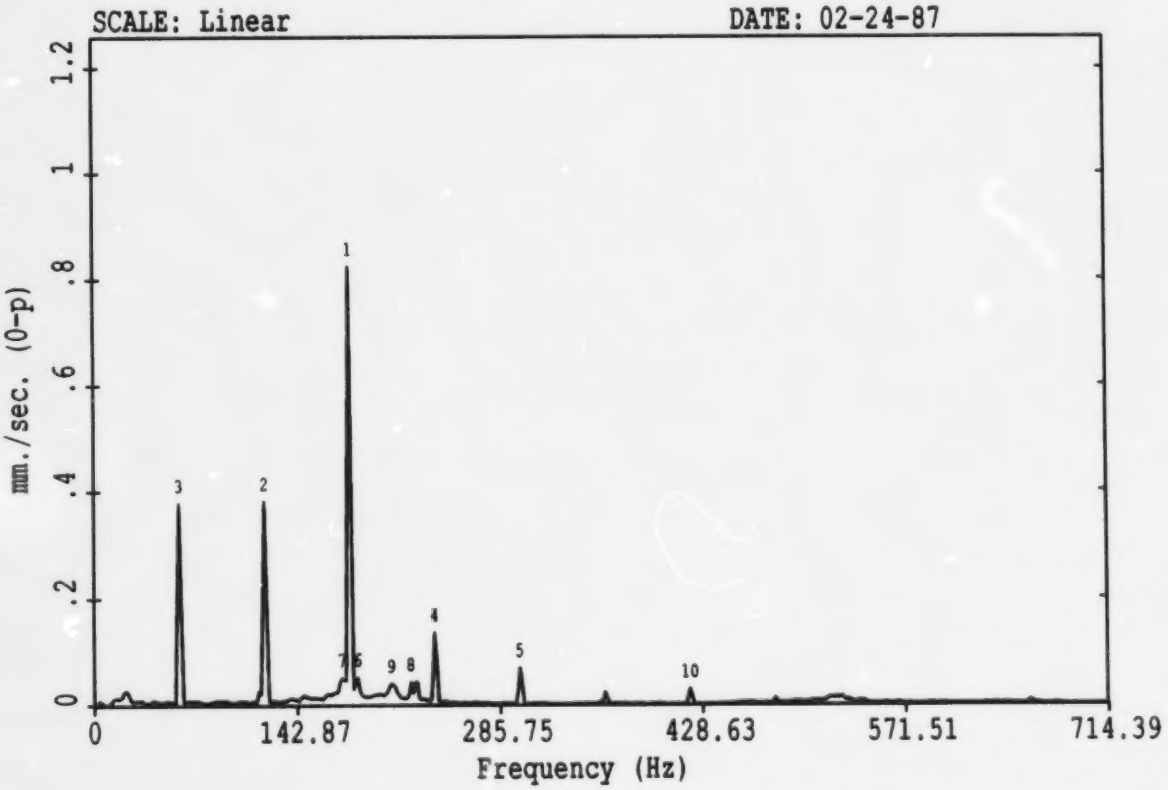


FIGURE 23
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.30
2	180.0	3.00	0.17
3	86.5	1.44	0.09
4	92.1	1.53	0.08
5	240.0	4.00	0.07
6	82.3	1.37	0.06
7	120.0	2.00	0.06
8	360.0	6.00	0.04
9	115.8	1.93	0.04
10	97.7	1.63	0.03

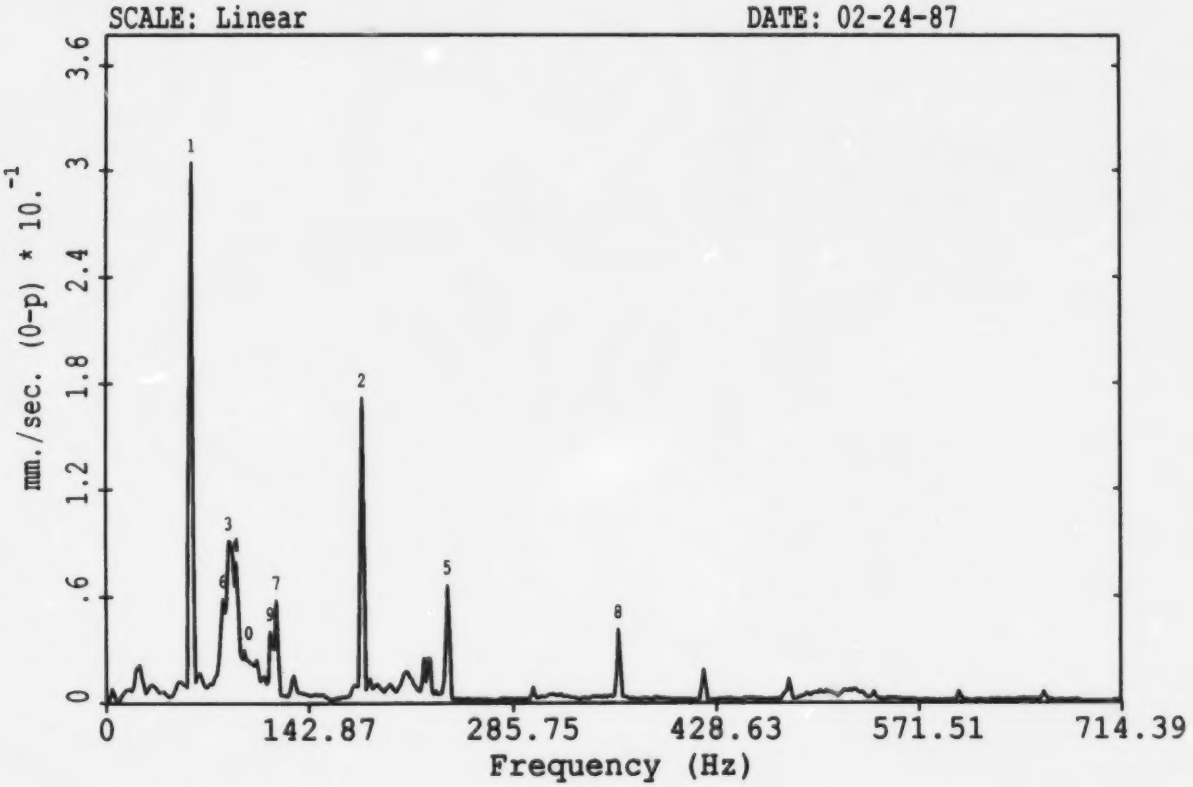


FIGURE 24

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.65
2	120.0	2.00	0.20
3	240.0	4.00	0.15
4	60.0	1.00	0.13
5	360.0	6.00	0.03

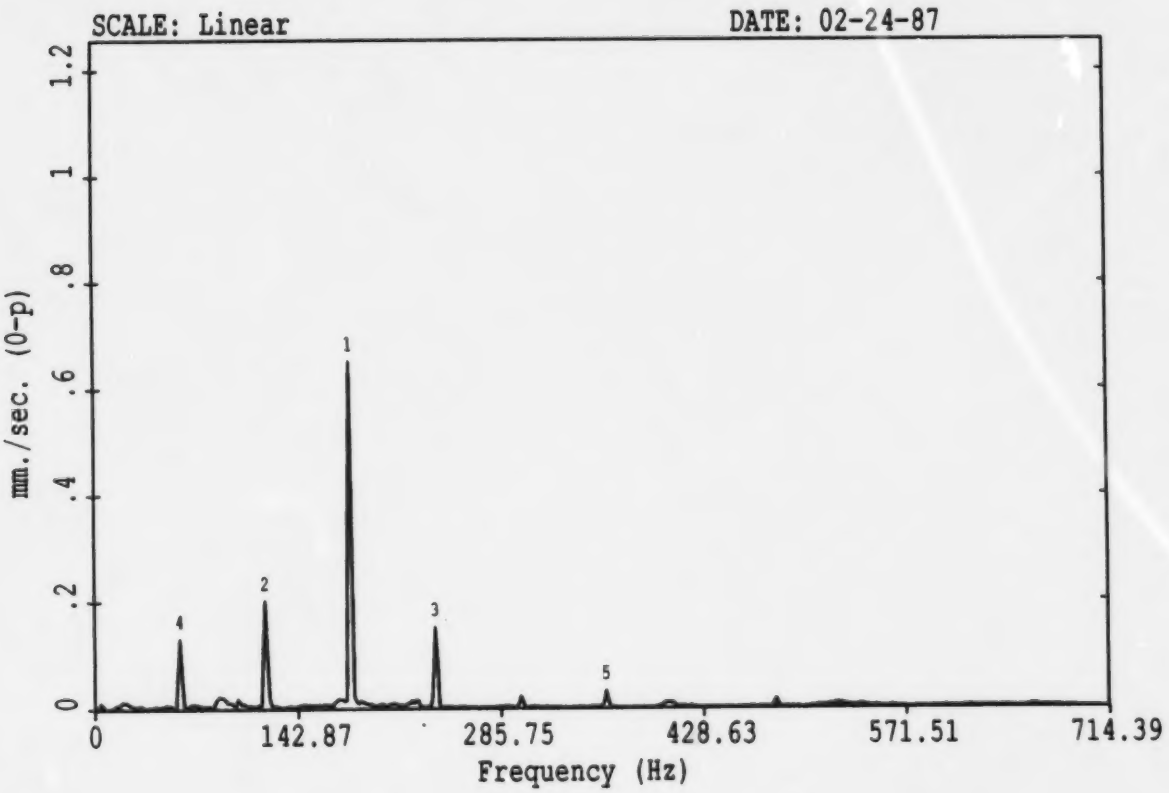


FIGURE 25
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.76
2	120.0	2.00	0.32
3	60.0	1.00	0.27
4	240.0	4.00	0.18
5	360.0	6.00	0.04
6	300.0	5.00	0.03
7	87.9	1.47	0.03

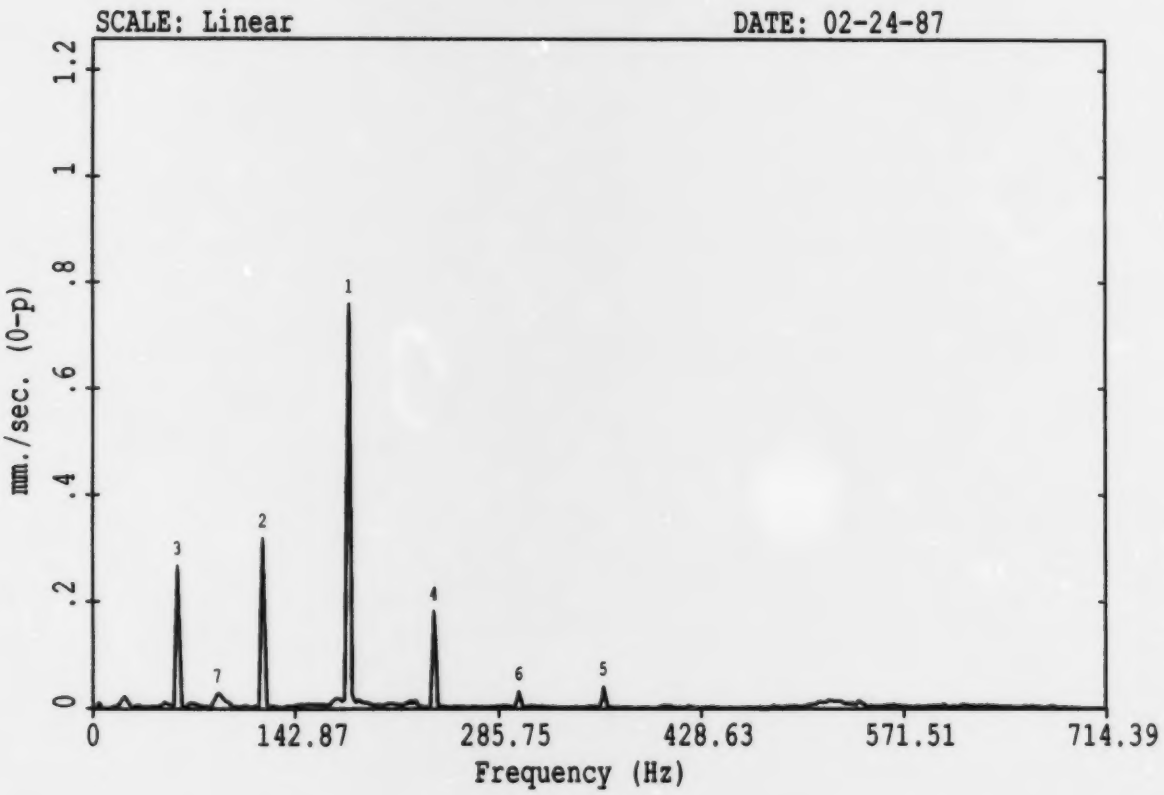


FIGURE 26

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.64
2	87.9	1.47	0.21
3	120.0	2.00	0.07
4	180.0	3.00	0.07
5	96.3	1.60	0.06
6	100.5	1.67	0.05
7	360.0	6.00	0.04
8	79.5	1.33	0.04
9	240.0	4.00	0.04
10	104.6	1.74	0.03

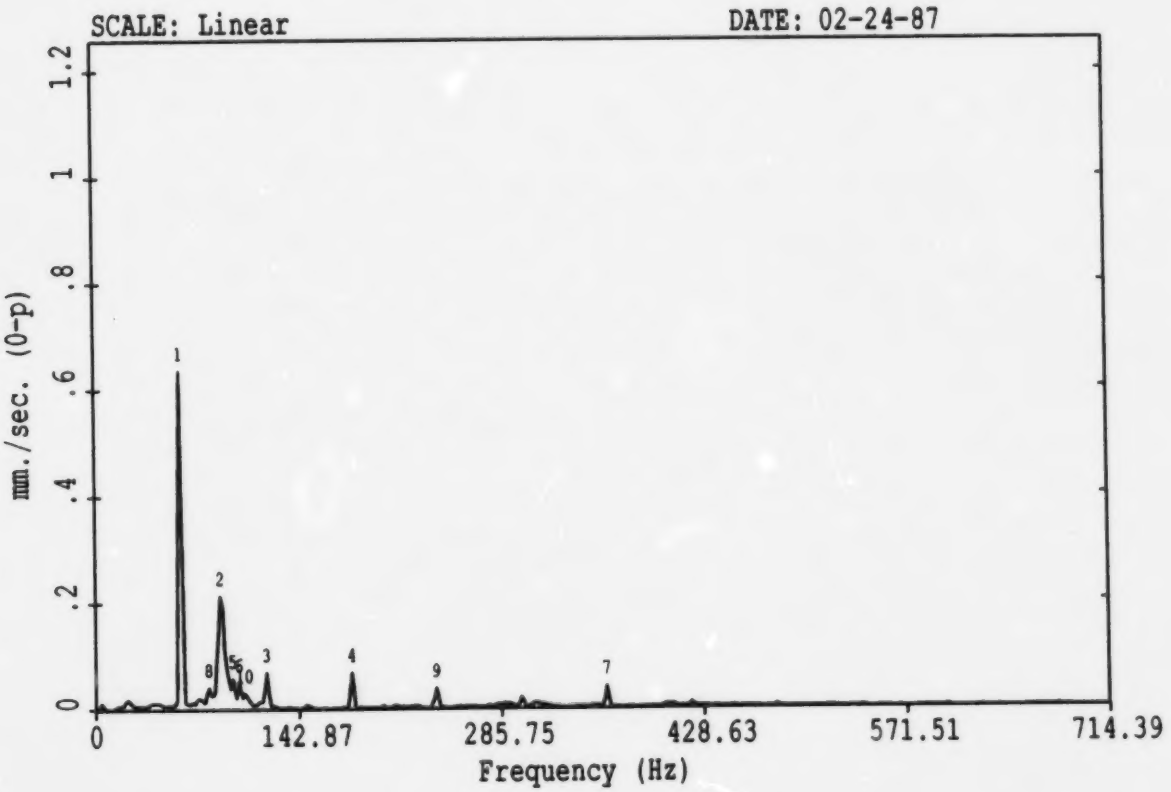


FIGURE 27
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.58
2	120.0	2.00	0.44
3	60.0	1.00	0.32
4	240.0	4.00	0.15
5	480.0	8.00	0.04
6	171.6	2.86	0.03
7	360.0	6.00	0.03
8	174.4	2.91	0.03
9	300.0	5.00	0.03
10	22.3	0.37	0.03

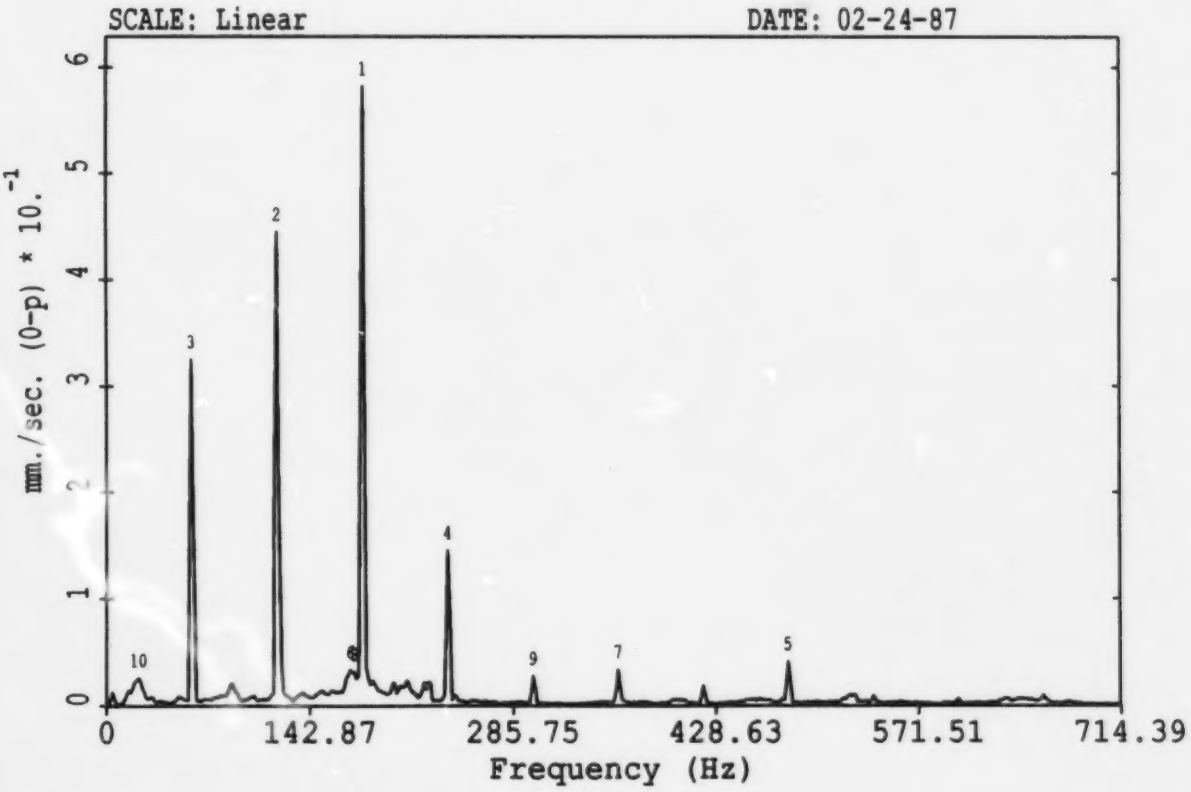


FIGURE 28

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.89
2	120.0	2.00	0.51
3	60.0	1.00	0.32
4	240.0	4.00	0.26
5	300.0	5.00	0.08
6	174.4	2.91	0.05
7	171.6	2.86	0.04
8	223.2	3.72	0.04
9	210.7	3.51	0.04
10	420.0	7.00	0.03

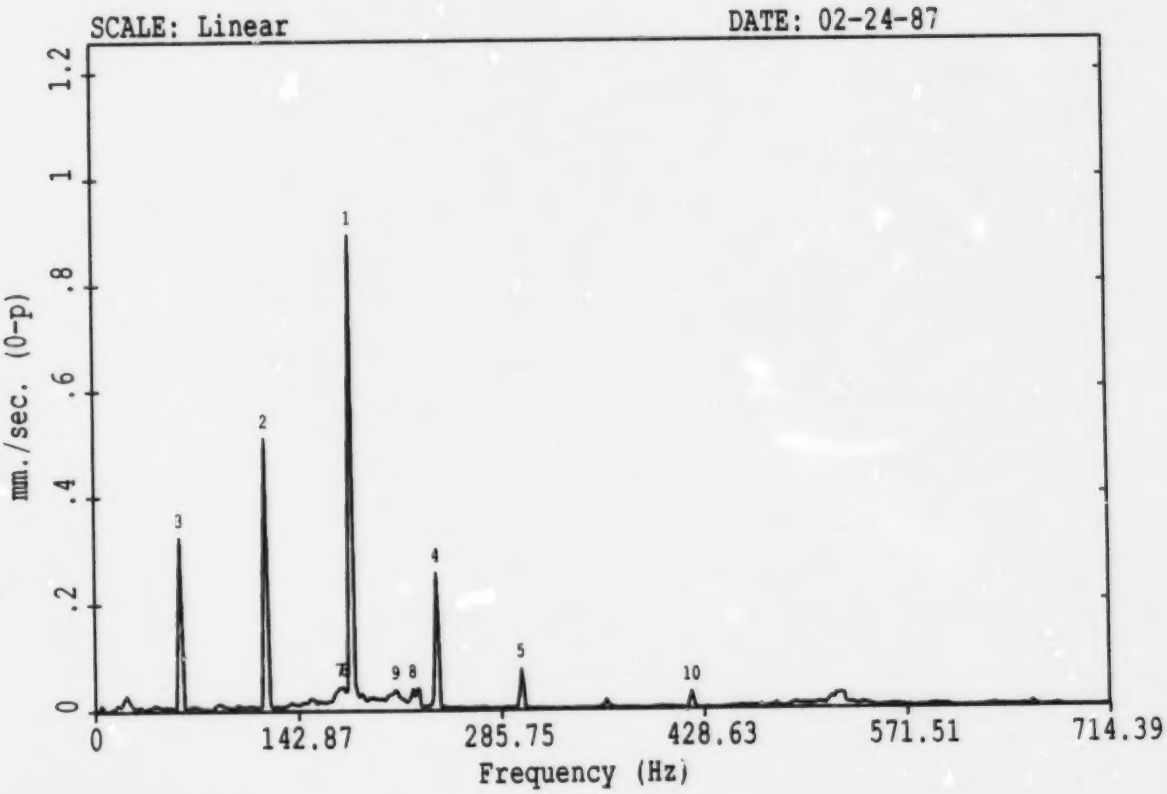


FIGURE 29

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.32
2	180.0	3.00	0.18
3	240.0	4.00	0.15
4	87.9	1.47	0.14
5	360.0	6.00	0.06
6	100.5	1.67	0.05
7	120.0	2.00	0.04
8	223.2	3.72	0.03
9	104.6	1.74	0.02
10	97.7	1.63	0.02

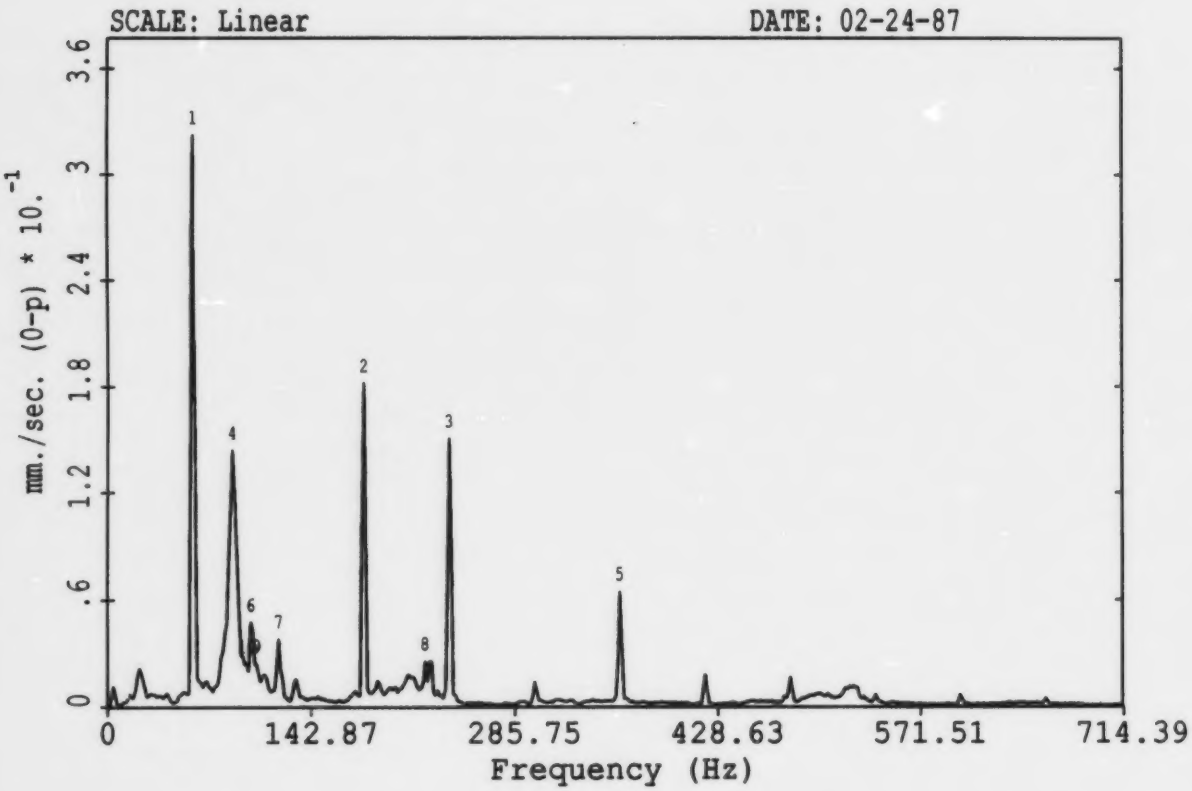


FIGURE 30

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.64
2	240.0	4.00	0.23
3	120.0	2.00	0.16
4	60.0	1.00	0.10
5	360.0	6.00	0.03
6	87.9	1.47	0.03
7	300.0	5.00	0.03

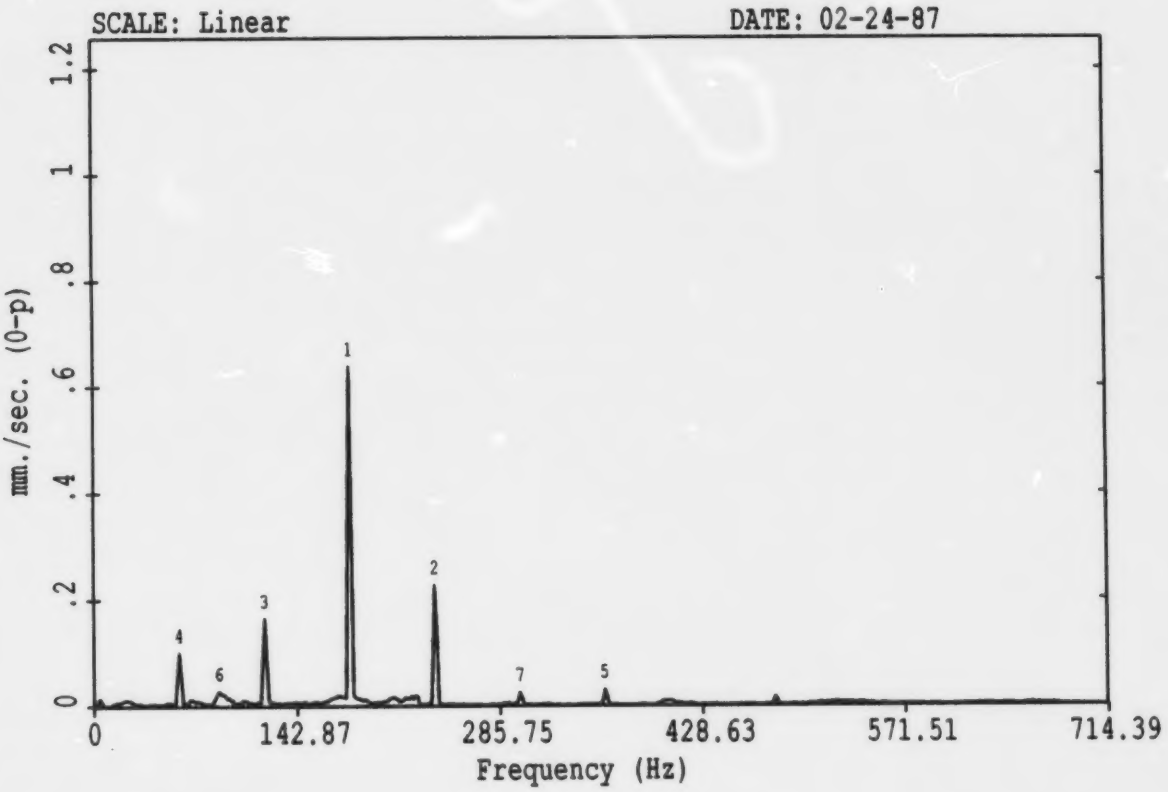


FIGURE 31
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.75
2	120.0	2.00	0.28
3	60.0	1.00	0.28
4	240.0	4.00	0.25
5	360.0	6.00	0.03
6	89.3	1.49	0.03
7	300.0	5.00	0.03

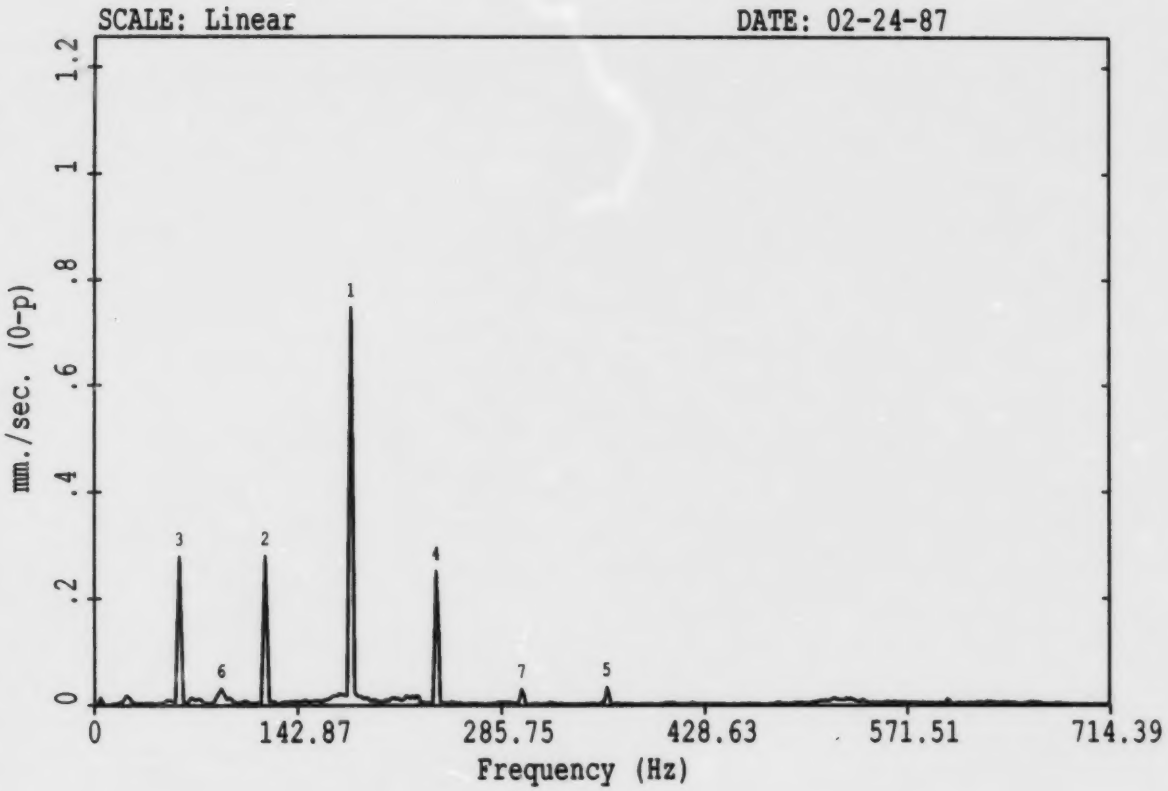


FIGURE 32

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.56
2	89.3	1.49	0.21
3	120.0	2.00	0.12
4	96.3	1.60	0.08
5	240.0	4.00	0.06
6	360.0	6.00	0.05
7	180.0	3.00	0.04
8	104.6	1.74	0.04
9	79.5	1.33	0.04
10	72.6	1.21	0.02

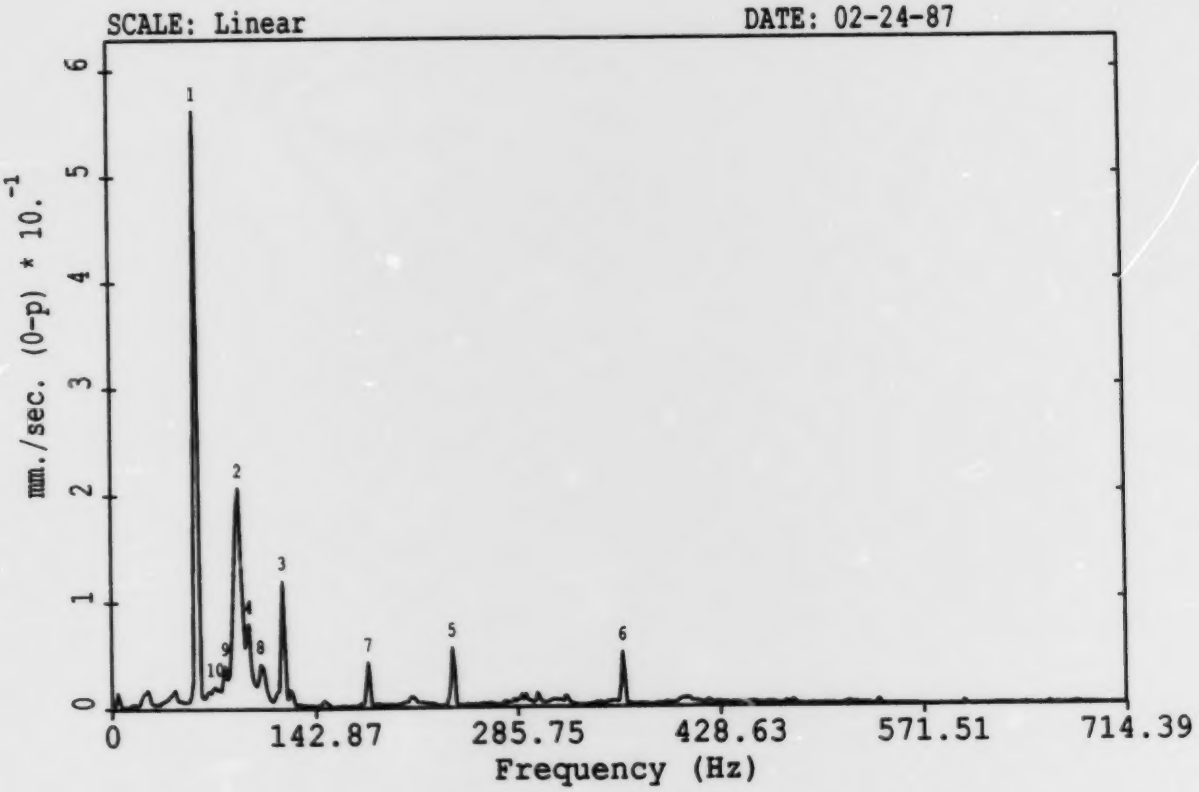


FIGURE 33

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.59
2	120.0	2.00	0.49
3	60.0	1.00	0.35
4	240.0	4.00	0.24
5	360.0	6.00	0.05
6	171.6	2.86	0.04
7	480.0	8.00	0.03
8	210.7	3.51	0.03
9	187.0	3.12	0.03
10	223.2	3.72	0.03

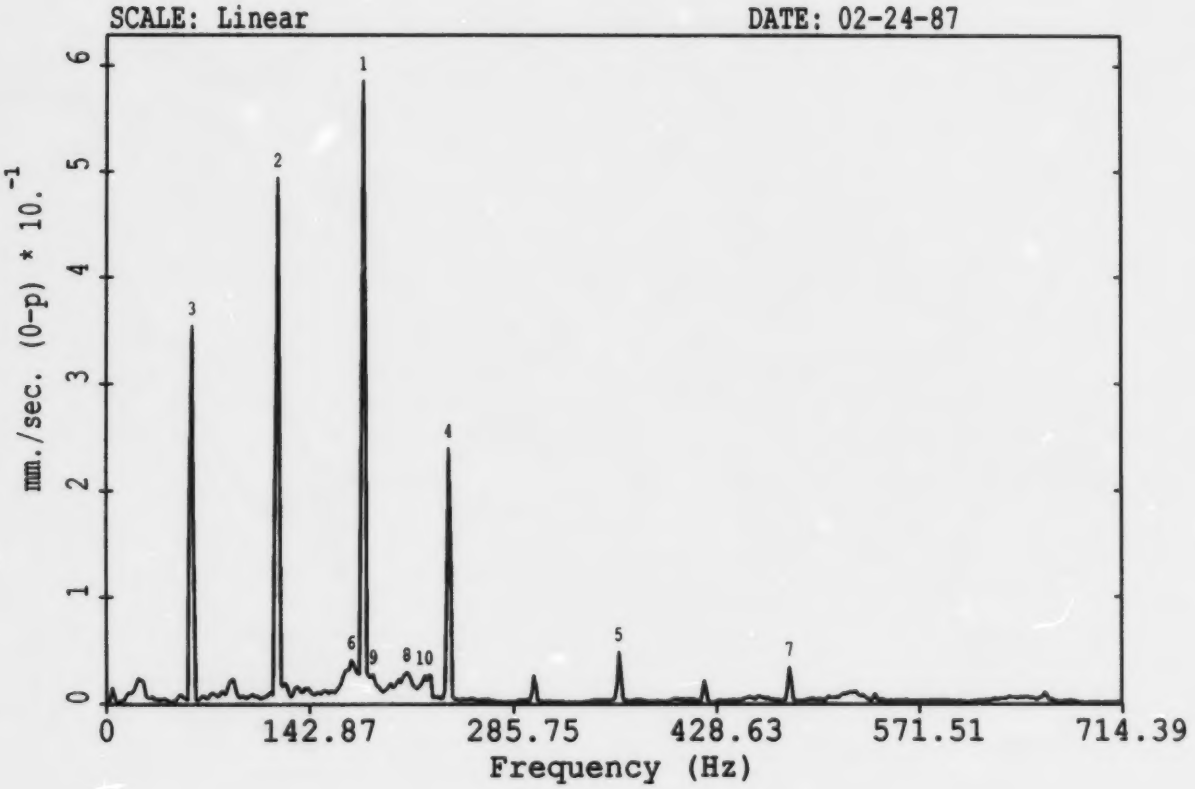


FIGURE 34
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	180.0	3.00	0.91
2	120.0	2.00	0.58
3	60.0	1.00	0.38
4	240.0	4.00	0.35
5	300.0	5.00	0.08
6	223.2	3.72	0.05
7	171.6	2.86	0.05
8	213.5	3.56	0.05
9	209.3	3.49	0.05
10	205.1	3.42	0.04

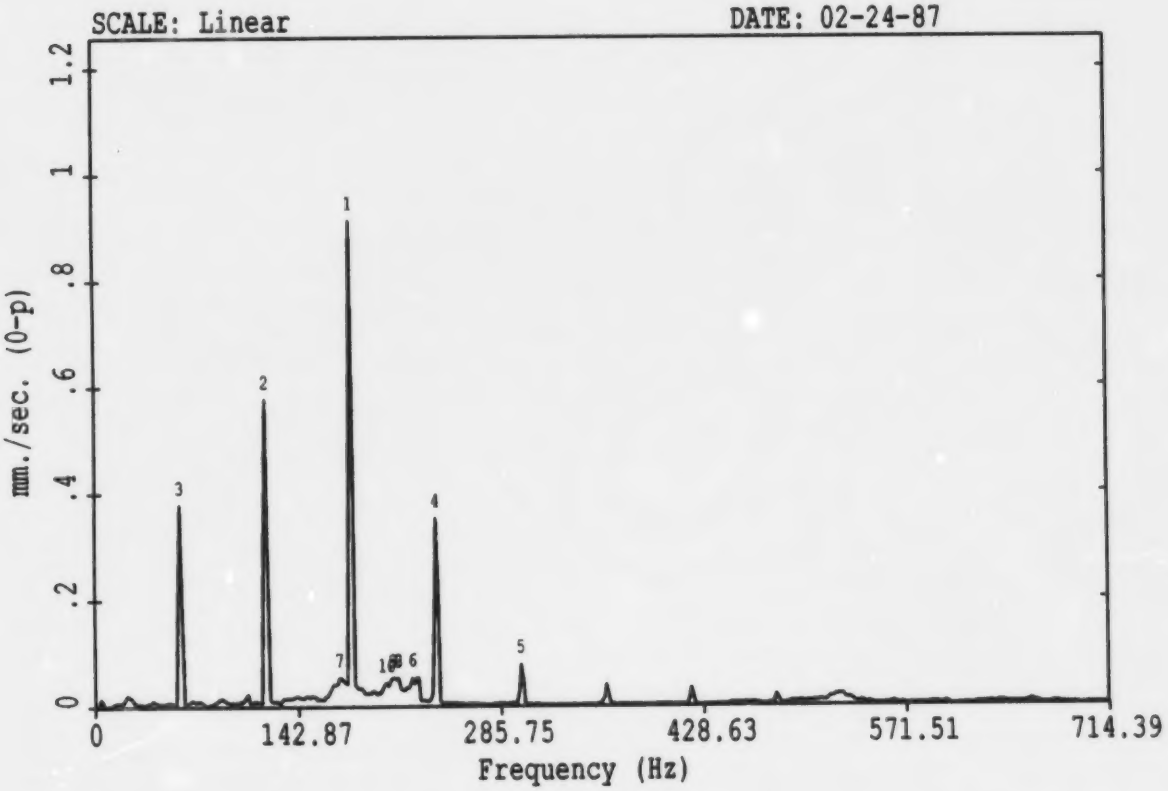


FIGURE 35
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.28
2	240.0	4.00	0.25
3	89.3	1.49	0.17
4	180.0	3.00	0.13
5	120.0	2.00	0.09
6	107.4	1.79	0.08
7	82.3	1.37	0.04
8	360.0	6.00	0.04
9	132.6	2.21	0.03
10	97.7	1.63	0.03

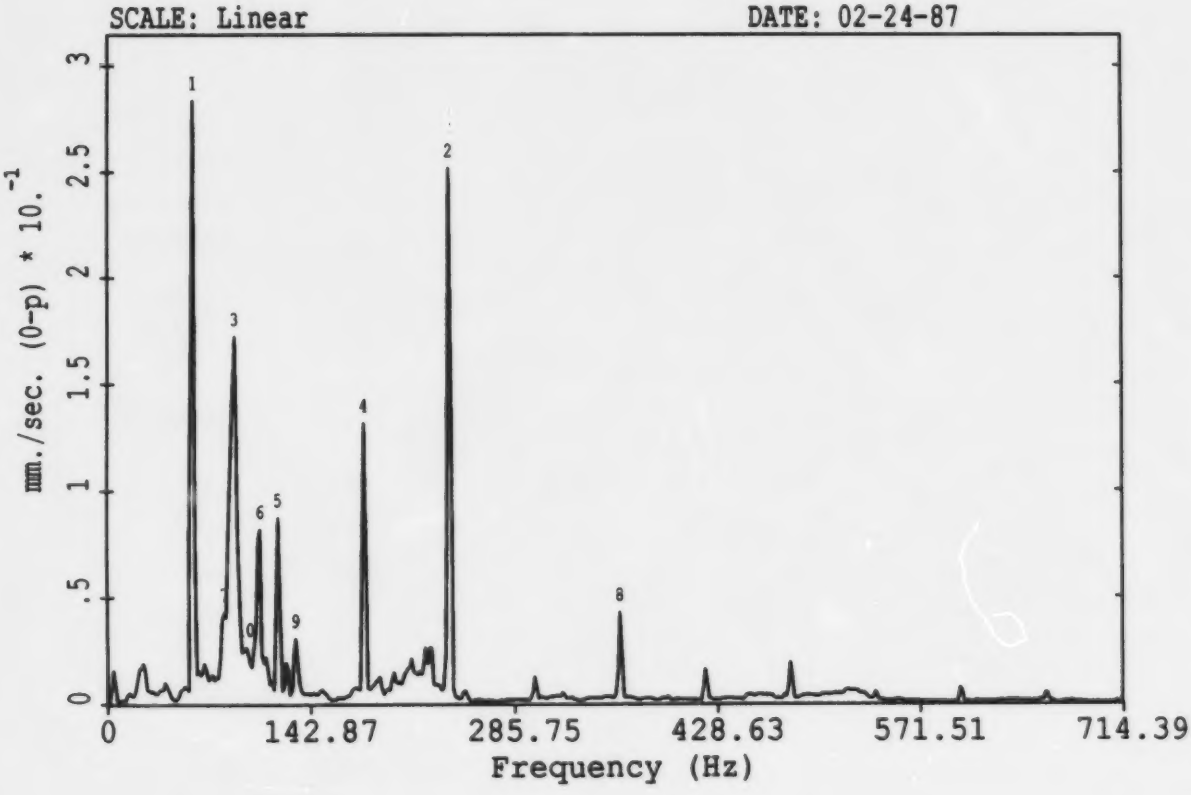


FIGURE 36

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.90
2	19.5	0.33	0.84
3	15.3	0.26	0.48
4	100.5	1.67	0.33
5	29.3	0.49	0.18
6	40.5	0.67	0.17
7	238.6	3.98	0.14
8	74.0	1.23	0.08
9	107.4	1.79	0.07
10	120.0	2.00	0.07

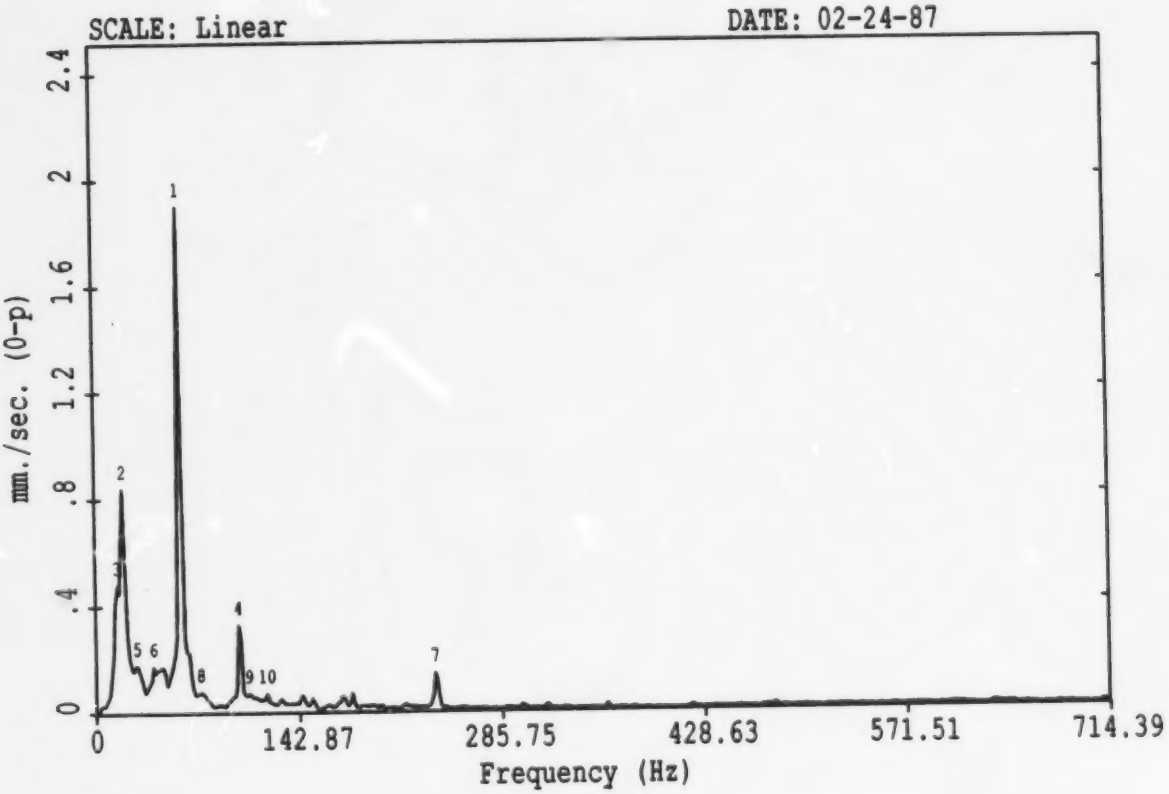


FIGURE 37

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.52
2	15.3	0.26	0.45
3	32.1	0.53	0.18
4	100.5	1.67	0.15
5	120.0	2.00	0.13
6	46.0	0.77	0.13
7	69.8	1.16	0.12
8	36.3	0.60	0.10
9	76.7	1.28	0.09
10	180.0	3.00	0.08

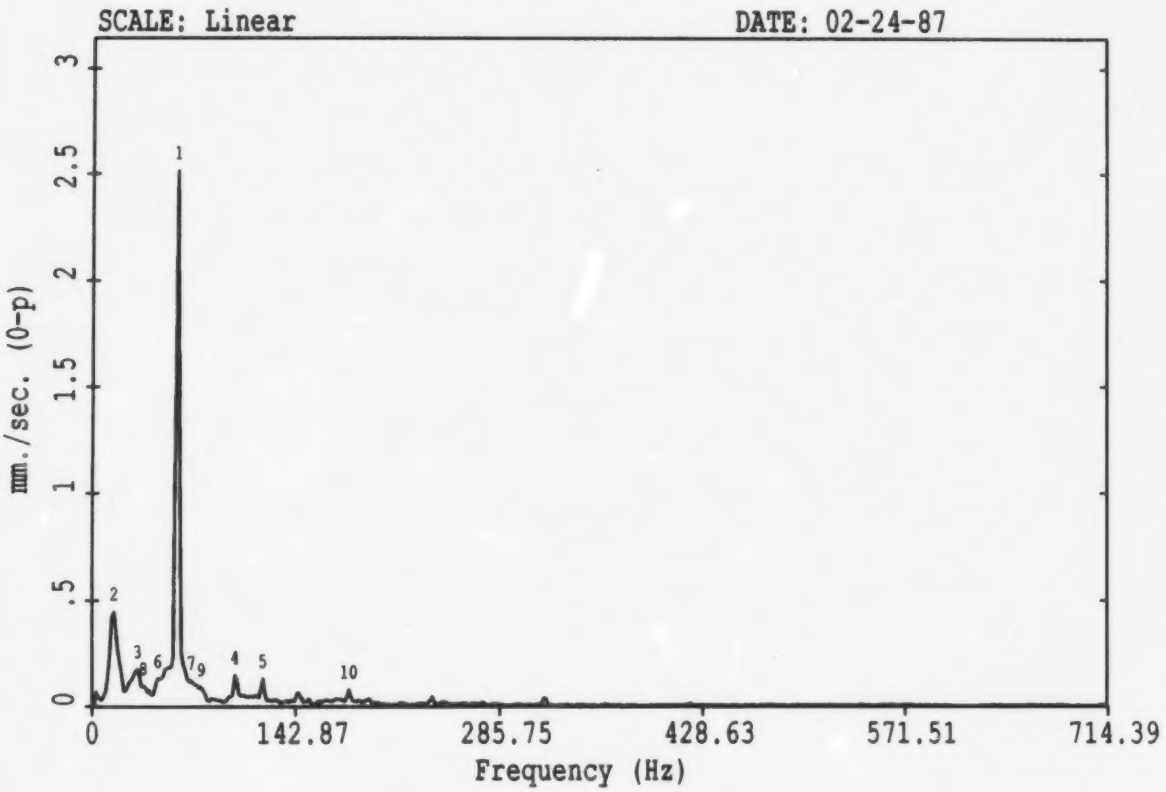


FIGURE 38

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.95
2	19.5	0.33	0.87
3	60.0	1.00	0.54
4	40.5	0.67	0.27
5	32.1	0.53	0.27
6	36.3	0.60	0.24
7	46.0	0.77	0.16
8	120.0	2.00	0.15
9	316.7	5.28	0.08
10	53.0	0.88	0.08

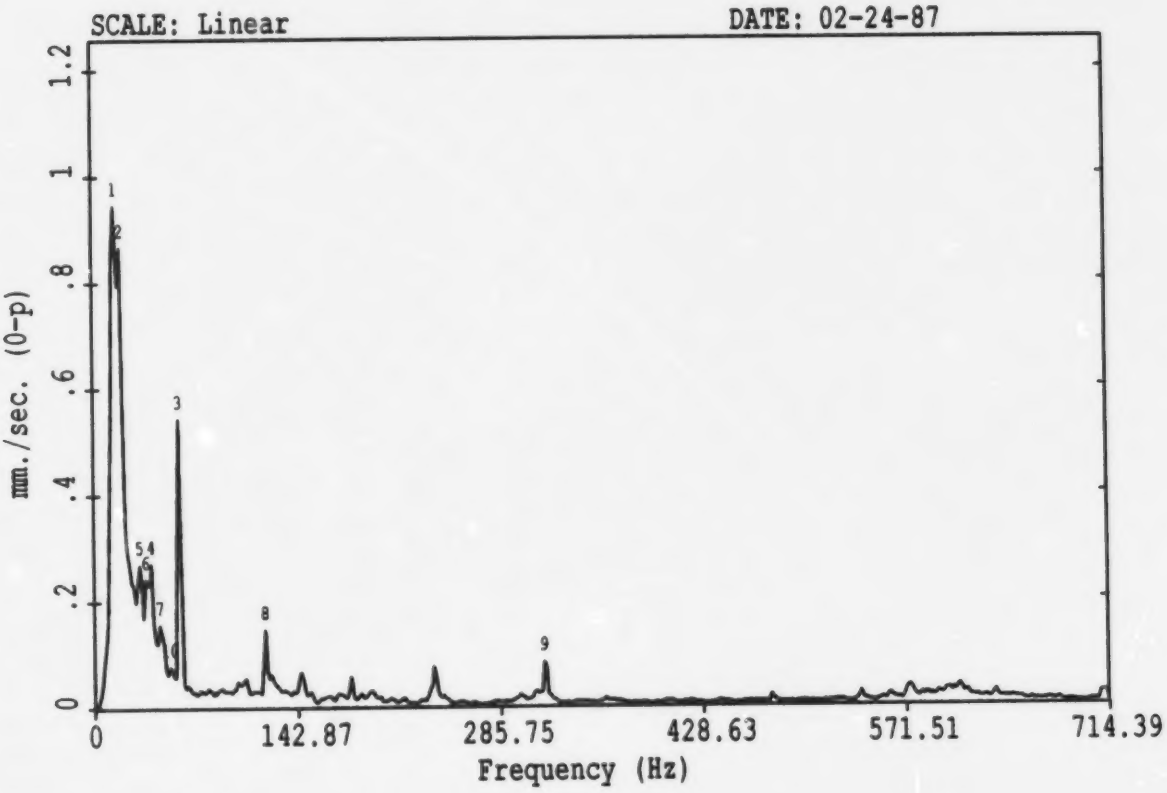


FIGURE 39

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.82
2	19.5	0.33	0.82
3	15.3	0.26	0.56
4	51.6	0.86	0.17
5	54.4	0.91	0.17
6	110.2	1.84	0.16
7	64.2	1.07	0.15
8	29.3	0.49	0.15
9	44.6	0.74	0.12
10	40.5	0.67	0.12

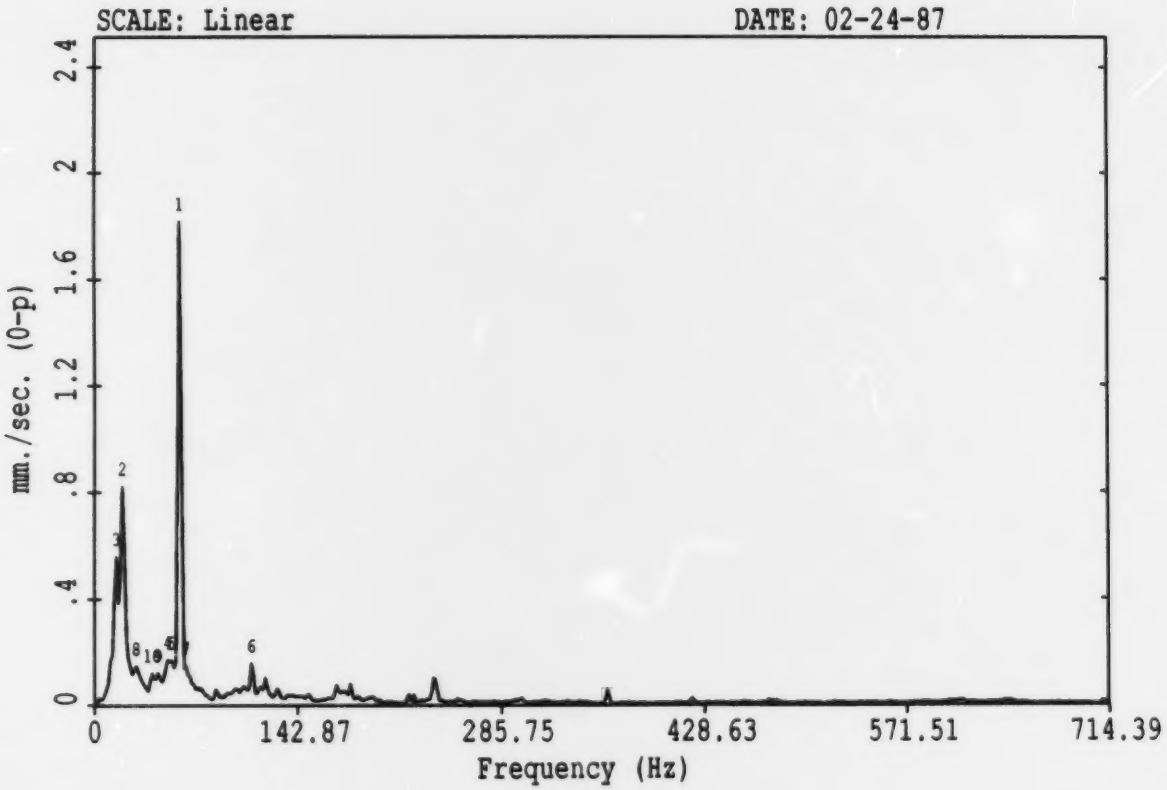


FIGURE 40

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.36
2	15.3	0.26	0.55
3	53.0	0.88	0.23
4	69.8	1.16	0.19
5	67.0	1.12	0.18
6	32.1	0.53	0.16
7	120.0	2.00	0.14
8	46.0	0.77	0.12
9	170.2	2.84	0.11
10	75.3	1.26	0.11

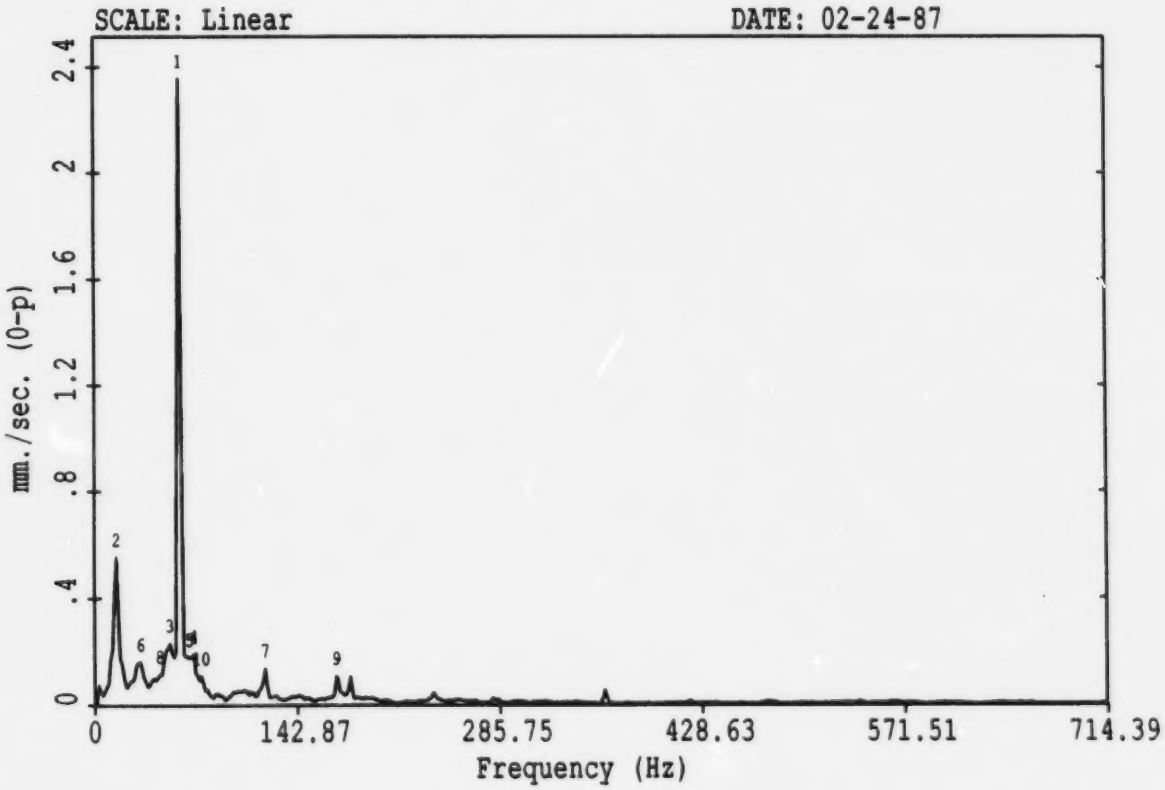


FIGURE 41

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	1.13
2	19.5	0.33	0.91
3	60.0	1.00	0.67
4	40.5	0.67	0.44
5	36.3	0.60	0.27
6	32.1	0.53	0.22
7	27.9	0.47	0.19
8	48.8	0.81	0.15
9	53.0	0.88	0.10
10	120.0	2.00	0.09

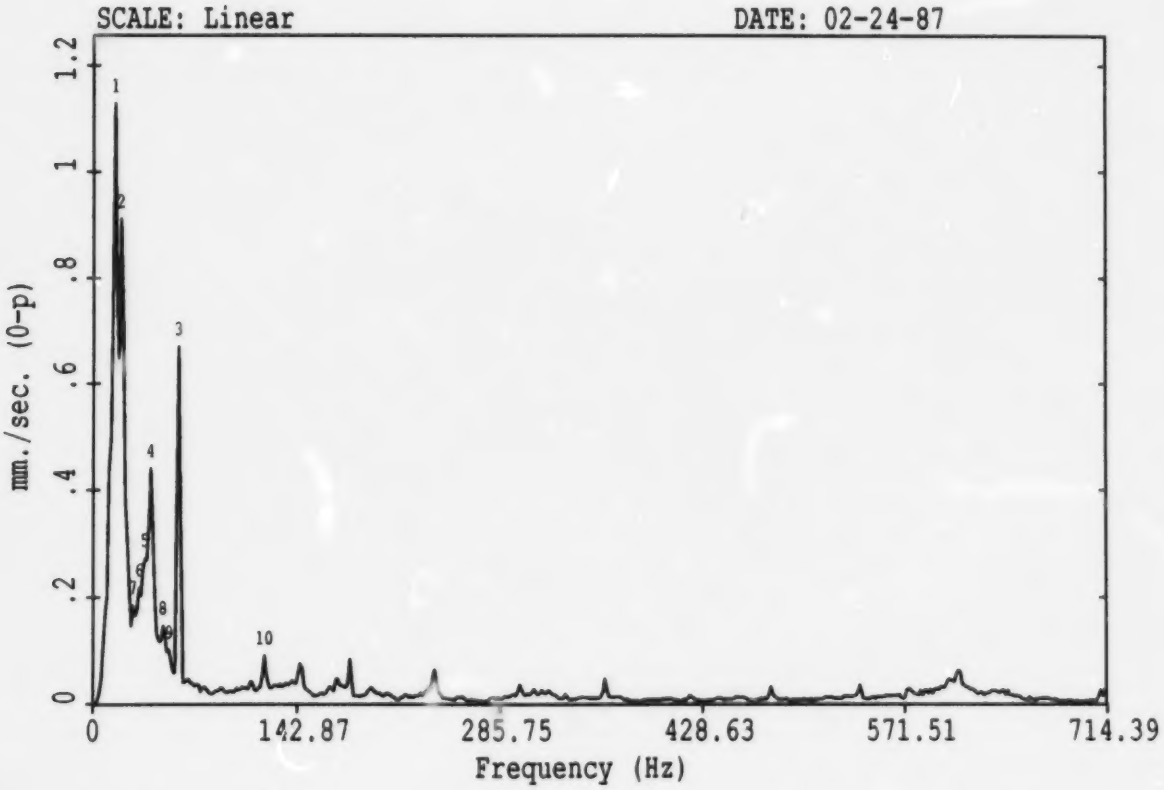


FIGURE 42

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.95
2	19.5	0.33	0.59
3	15.3	0.26	0.48
4	115.8	1.93	0.30
5	51.6	0.86	0.21
6	30.7	0.51	0.14
7	240.0	4.00	0.11
8	120.0	2.00	0.11
9	180.0	3.00	0.10
10	40.5	0.67	0.08

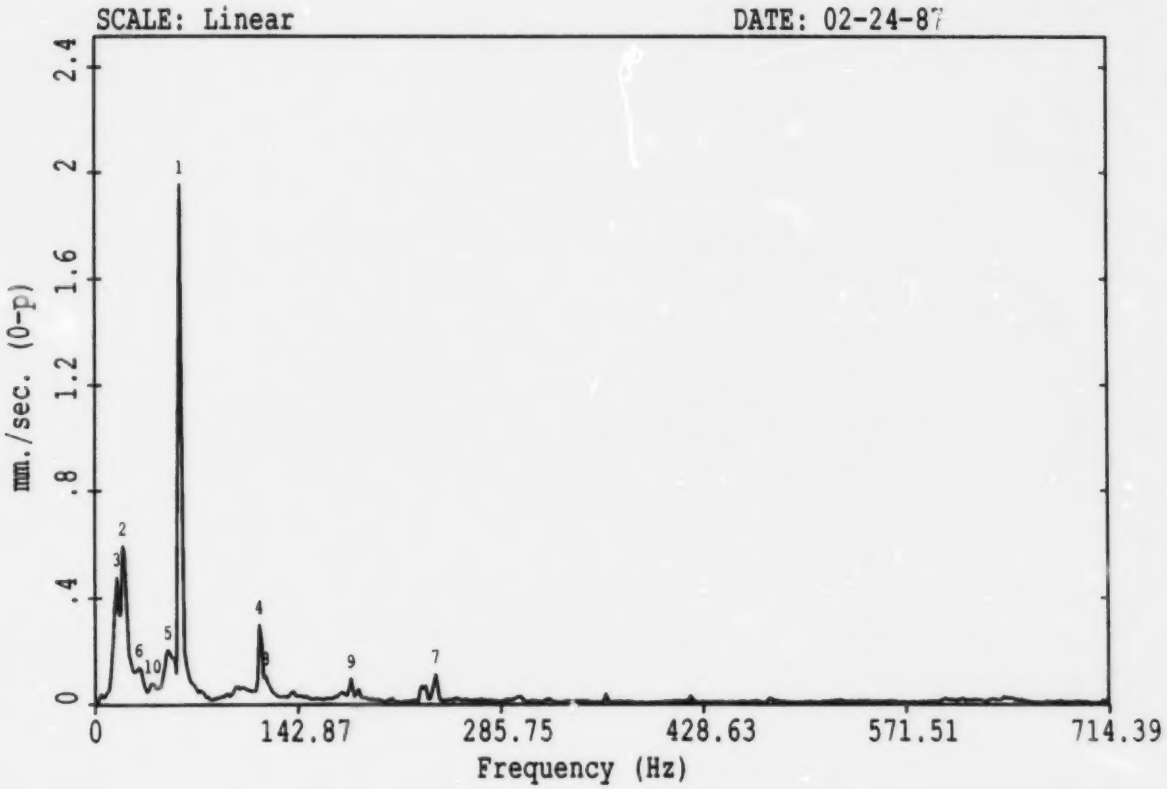


FIGURE 43
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.33
2	15.3	0.26	0.51
3	54.4	0.91	0.26
4	32.1	0.53	0.20
5	115.8	1.93	0.19
6	65.6	1.09	0.17
7	120.0	2.00	0.17
8	69.8	1.16	0.14
9	180.0	3.00	0.12
10	36.3	0.60	0.12

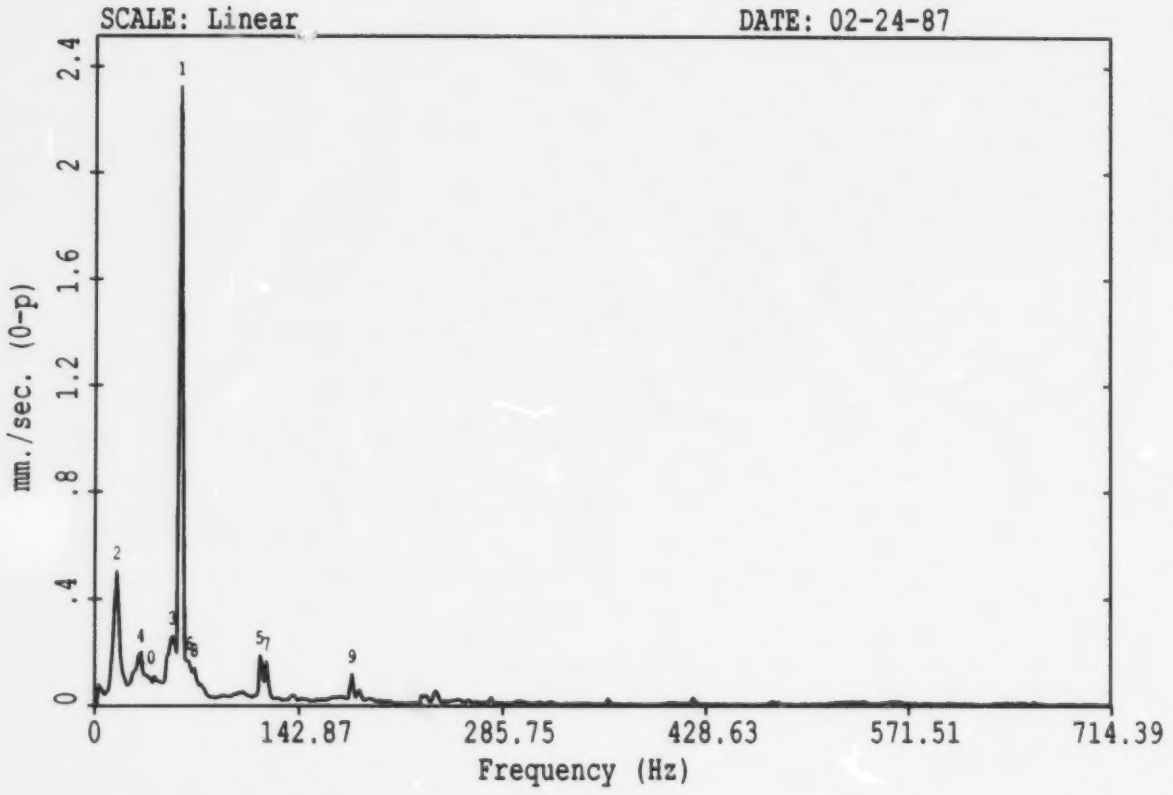


FIGURE 44
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.99
2	60.0	1.00	0.73
3	20.9	0.35	0.70
4	41.9	0.70	0.41
5	32.1	0.53	0.36
6	37.7	0.63	0.28
7	180.0	3.00	0.10
8	120.0	2.00	0.10
9	240.0	4.00	0.09
10	146.5	2.44	0.09

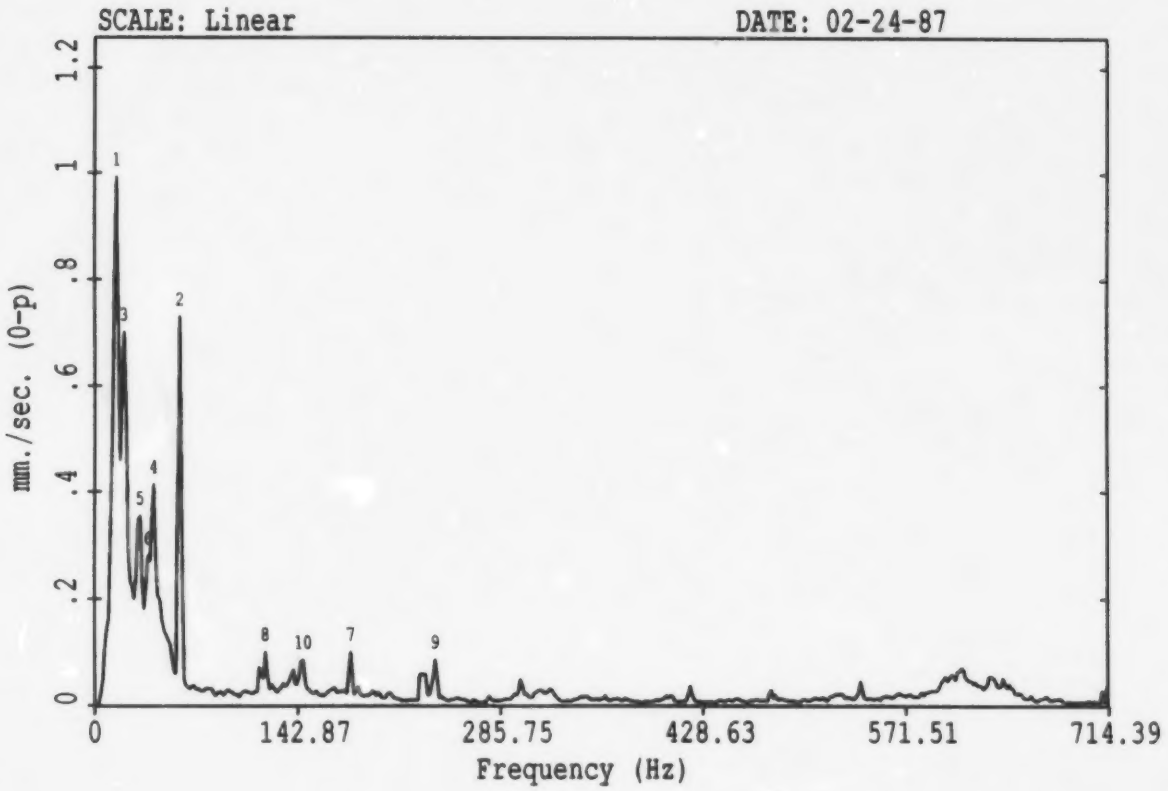


FIGURE 45
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.03
2	19.5	0.33	0.43
3	100.5	1.67	0.39
4	15.3	0.26	0.38
5	122.8	2.05	0.38
6	51.6	0.86	0.17
7	25.1	0.42	0.15
8	32.1	0.53	0.15
9	240.0	4.00	0.14
10	68.4	1.14	0.12

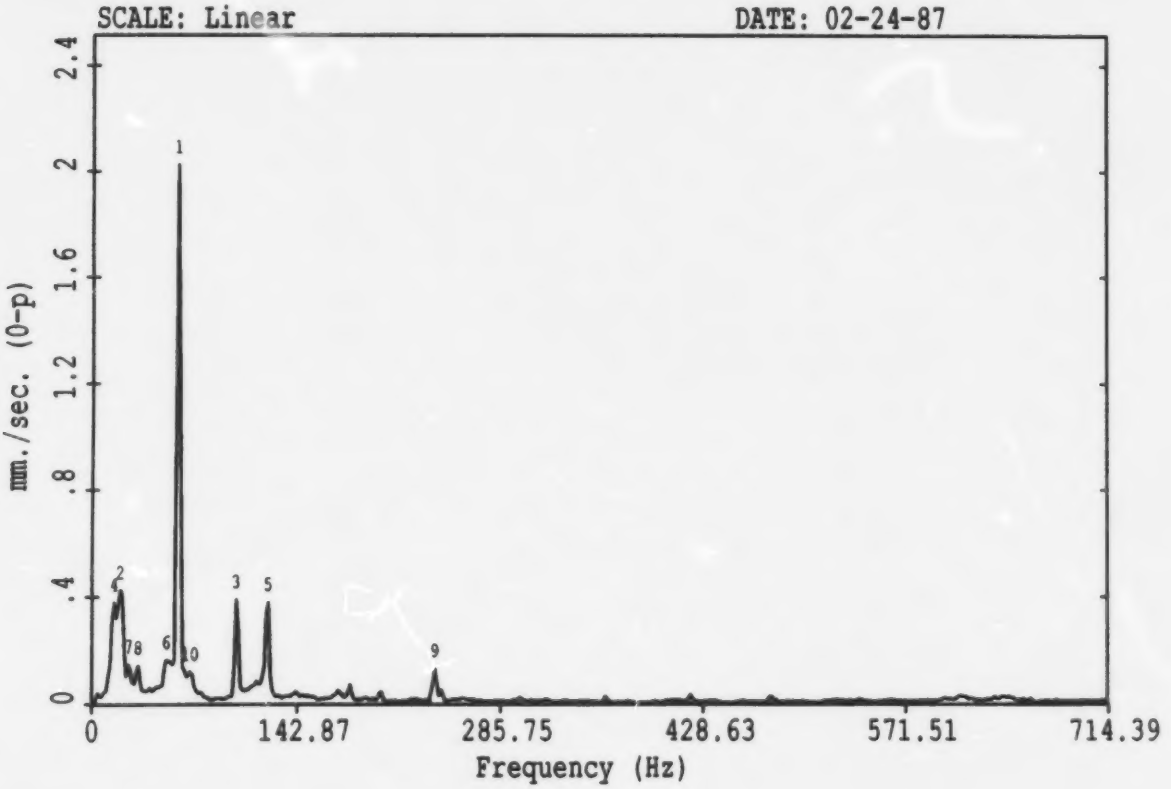


FIGURE 46
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.38
2	15.3	0.26	0.38
3	100.5	1.67	0.29
4	32.1	0.53	0.19
5	65.6	1.09	0.18
6	68.4	1.14	0.17
7	120.0	2.00	0.16
8	26.5	0.44	0.13
9	180.0	3.00	0.12
10	20.9	0.35	0.11

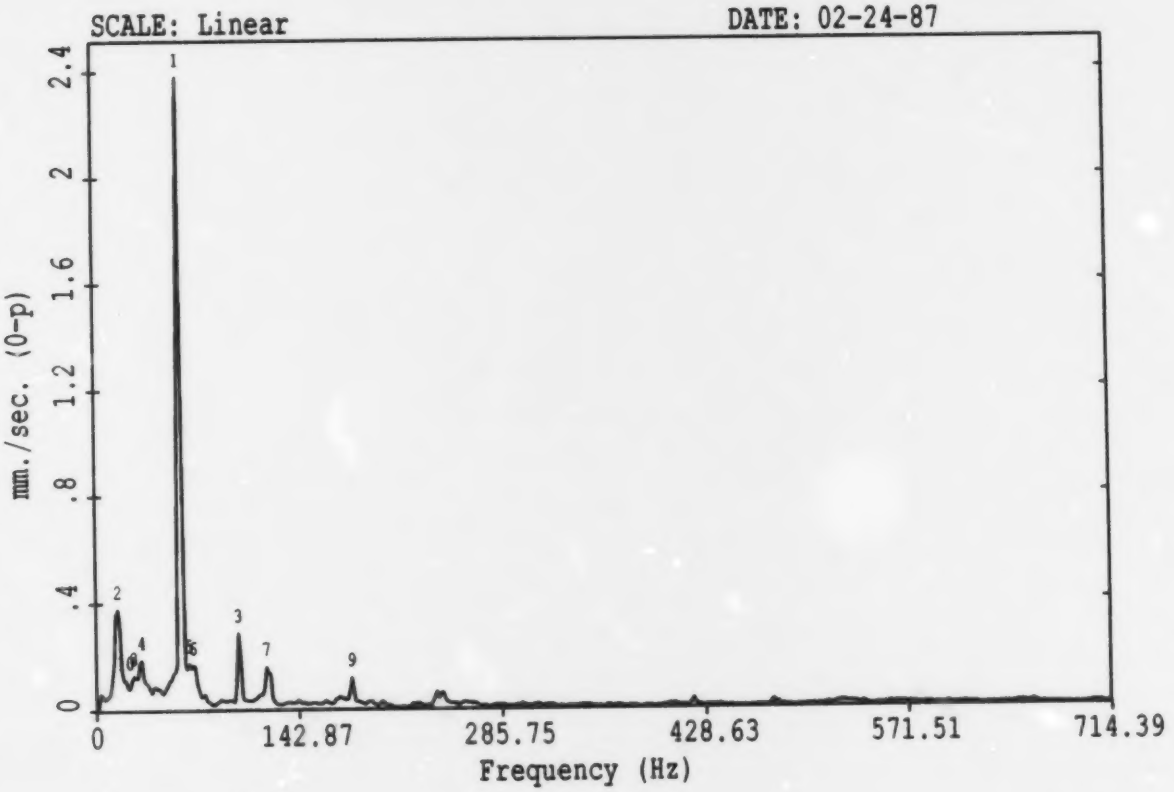


FIGURE 47

88 - 241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.73
2	60.0	1.00	0.73
3	20.9	0.35	0.56
4	41.9	0.70	0.49
5	32.1	0.53	0.30
6	25.1	0.42	0.22
7	8.4	0.14	0.15
8	120.0	2.00	0.14
9	609.7	10.16	0.12
10	240.0	4.00	0.11

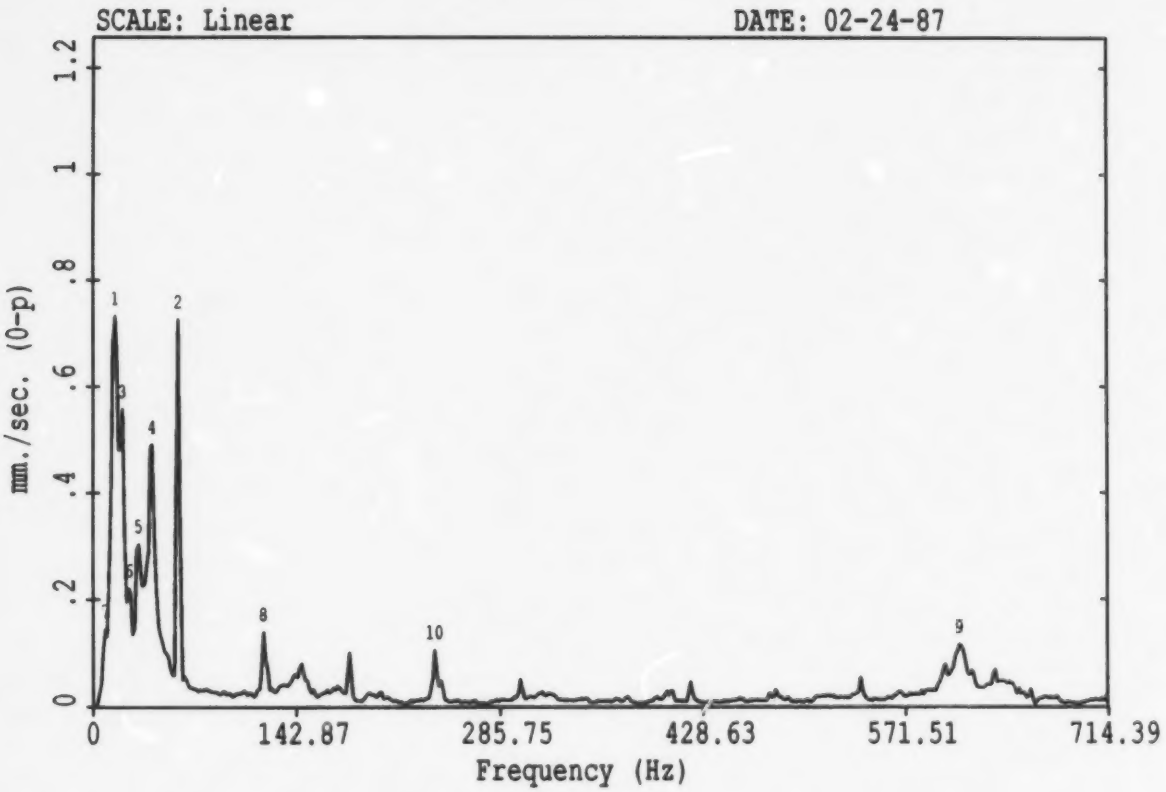


FIGURE 48

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.52
2	15.3	0.26	0.34
3	107.4	1.79	0.34
4	19.5	0.33	0.28
5	125.6	2.09	0.22
6	53.0	0.88	0.15
7	27.9	0.47	0.15
8	240.0	4.00	0.14
9	32.1	0.53	0.14
10	68.4	1.14	0.13

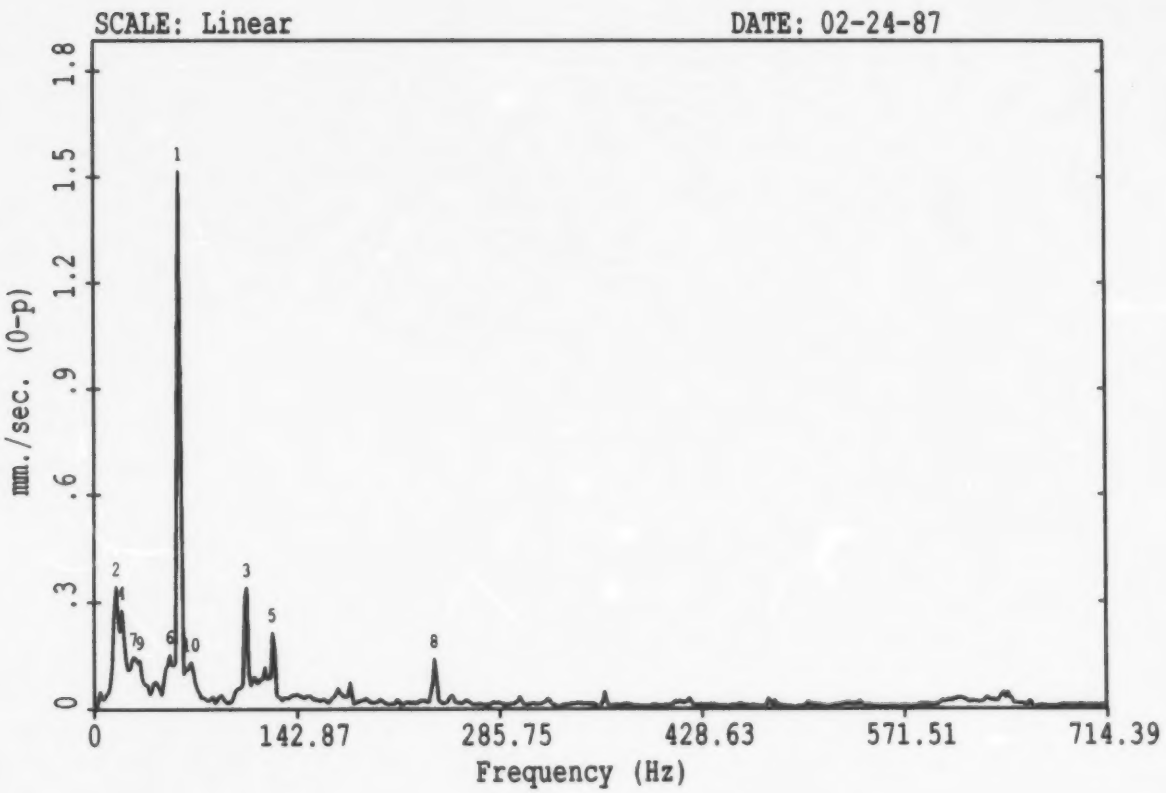


FIGURE 49

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.18
2	15.3	0.26	0.35
3	107.4	1.79	0.32
4	27.9	0.47	0.20
5	125.6	2.09	0.20
6	65.6	1.09	0.17
7	68.4	1.14	0.17
8	120.0	2.00	0.17
9	53.0	0.88	0.13
10	180.0	3.00	0.11

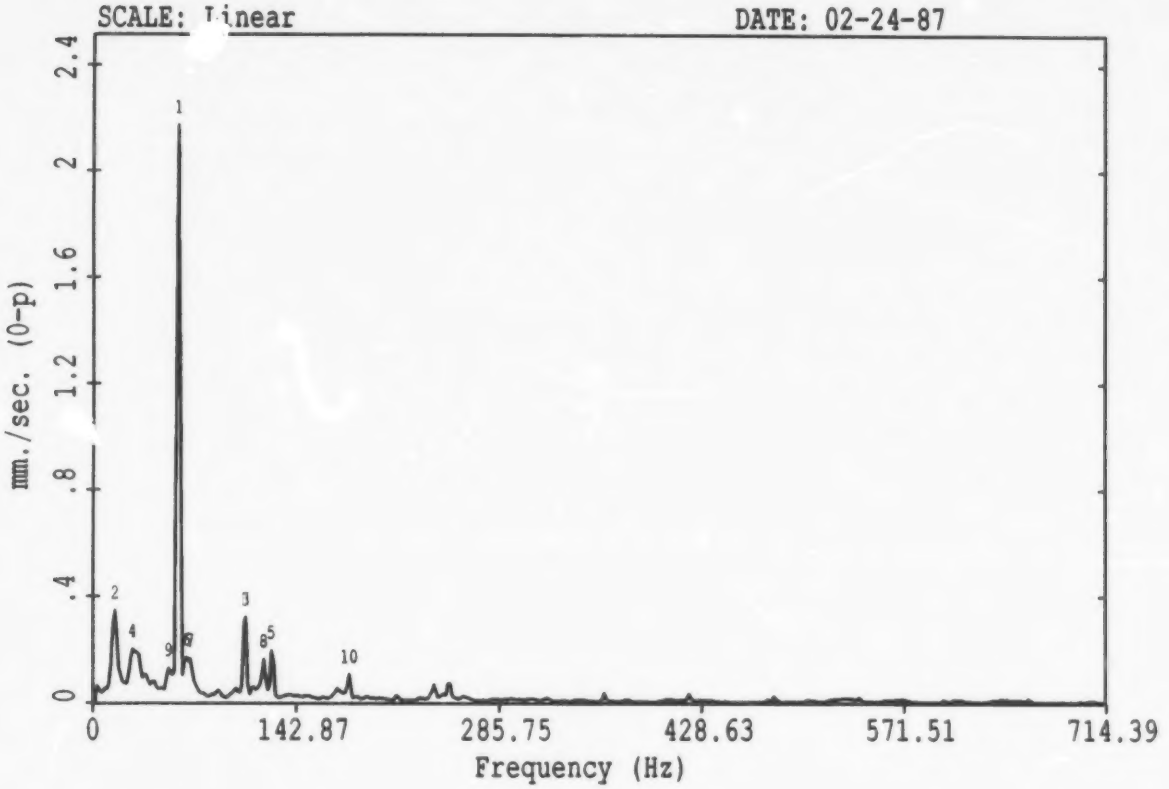


FIGURE 50

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.67
2	60.0	1.00	0.66
3	41.9	0.70	0.48
4	19.5	0.33	0.35
5	30.7	0.51	0.28
6	37.7	0.63	0.28
7	120.0	2.00	0.13
8	8.4	0.14	0.13
9	240.0	4.00	0.12
10	609.7	10.16	0.11

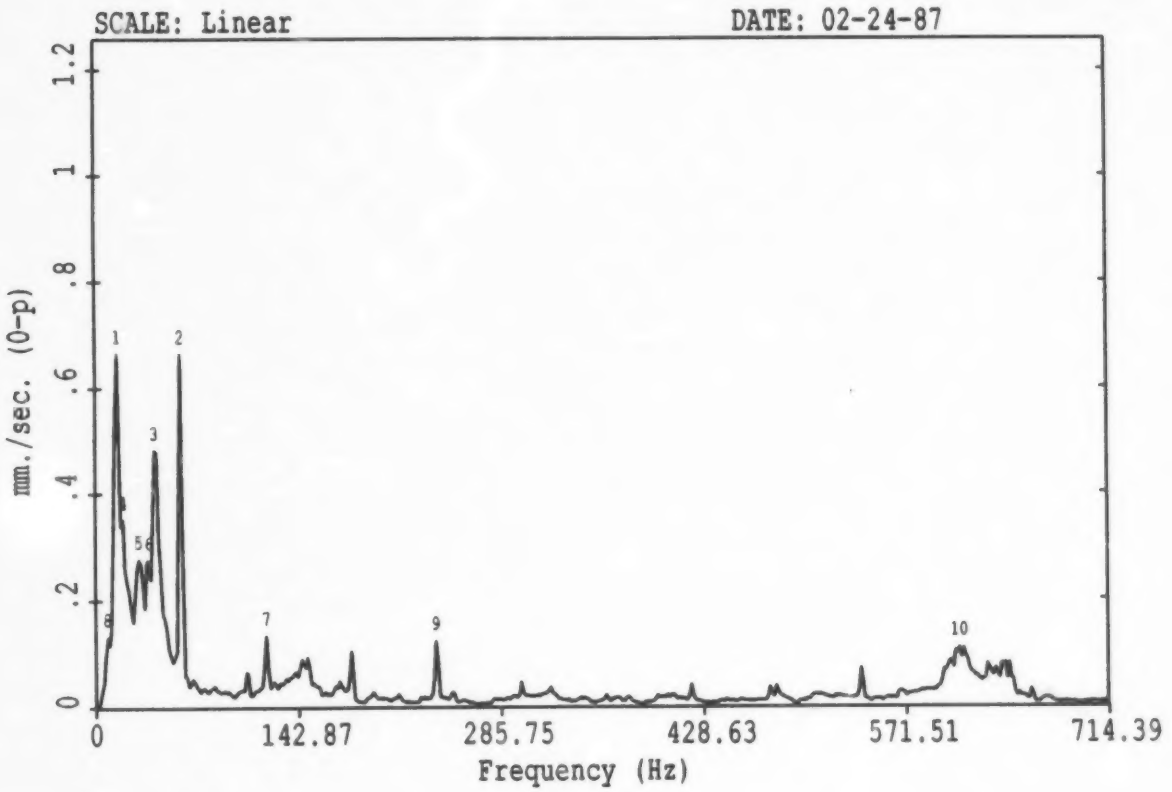


FIGURE 51

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	23.20
2	120.0	2.00	8.28
3	180.0	3.00	2.04
4	240.0	4.00	2.00
5	300.0	5.00	1.14
6	480.0	8.00	1.08
7	660.0	11.00	0.97
8	540.0	9.00	0.81
9	600.0	10.00	0.66
10	360.0	6.00	0.64

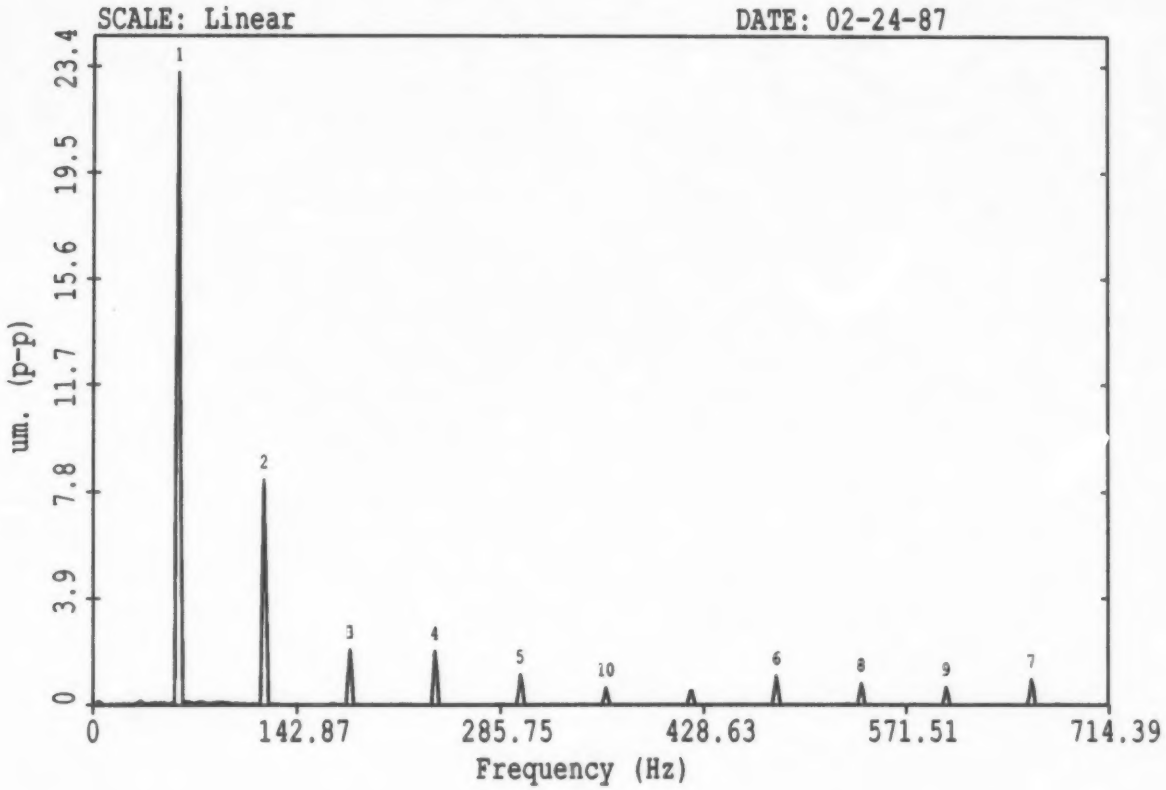


FIGURE 52

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	19.77
2	120.0	2.00	8.33
3	240.0	4.00	2.02
4	540.0	9.00	1.18
5	300.0	5.00	1.12
6	660.0	11.00	1.06
7	180.0	3.00	0.98
8	480.0	8.00	0.88
9	420.0	7.00	0.86
10	360.0	6.00	0.55

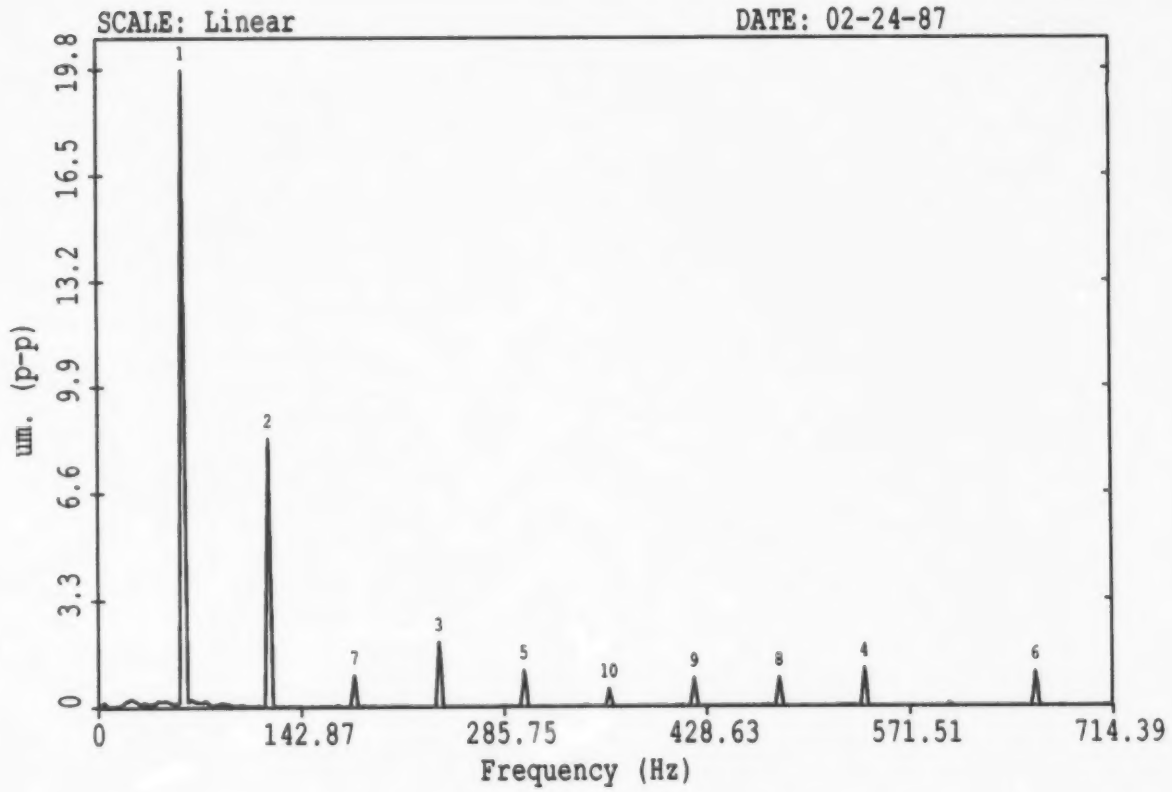


FIGURE 53

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	16.41
2	540.0	9.00	3.25
3	180.0	3.00	2.97
4	600.0	10.00	2.63
5	660.0	11.00	2.45
6	480.0	8.00	2.40
7	420.0	7.00	1.88
8	120.0	2.00	1.76
9	360.0	6.00	1.68
10	240.0	4.00	0.83

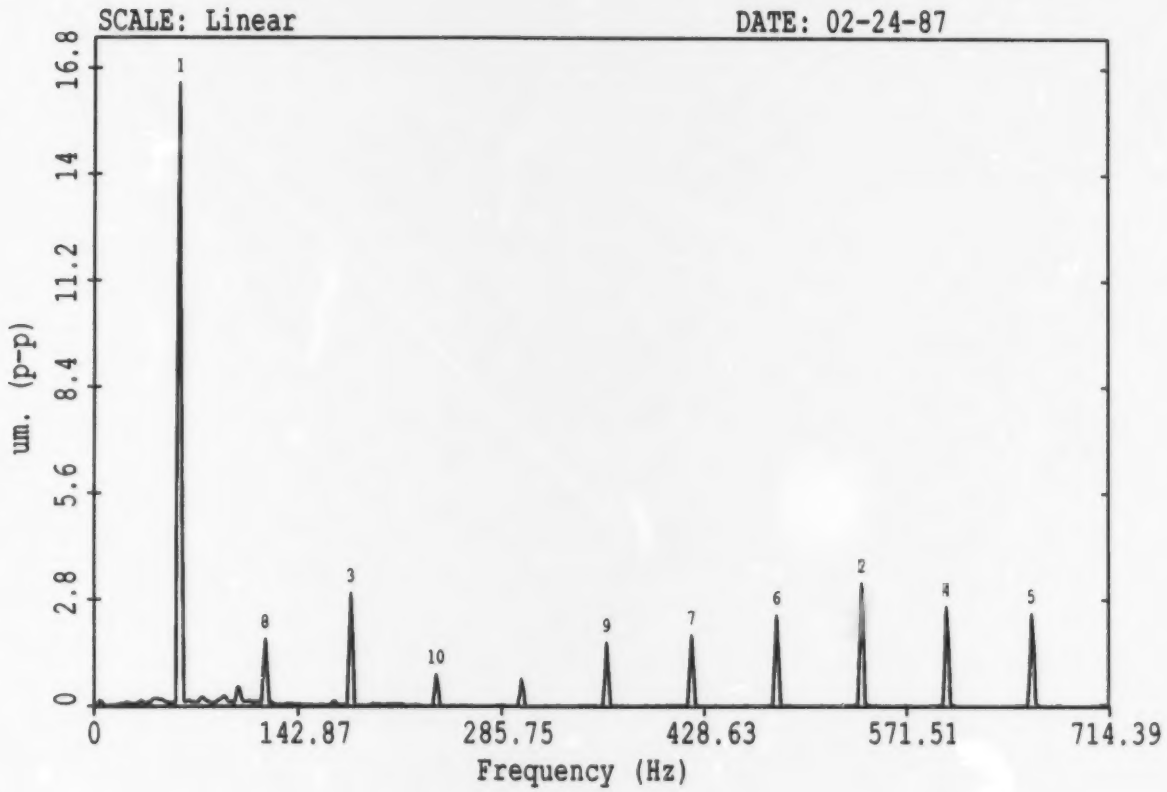


FIGURE 54

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	19.61
2	540.0	9.00	3.09
3	180.0	3.00	2.72
4	600.0	10.00	2.65
5	660.0	11.00	2.34
6	480.0	8.00	2.29
7	420.0	7.00	2.15
8	360.0	6.00	1.77
9	300.0	5.00	0.96
10	120.0	2.00	0.80

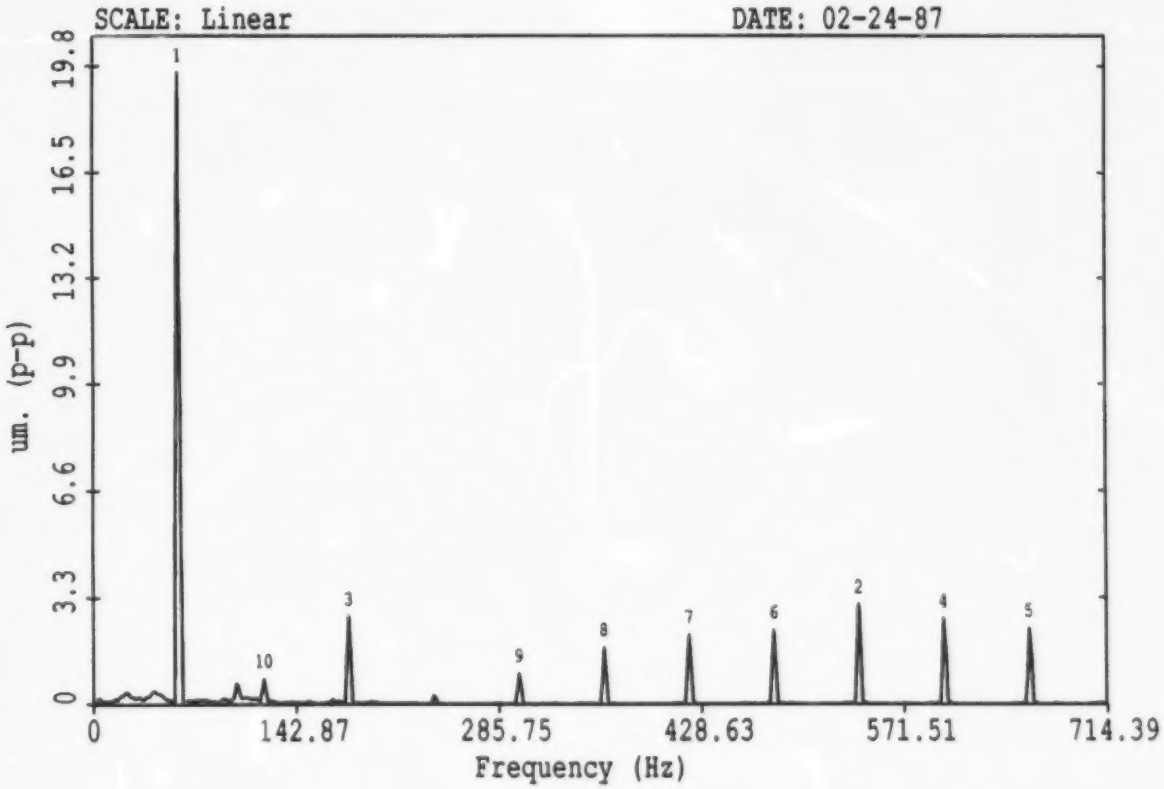


FIGURE 55

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	22.44
2	120.0	2.00	8.33
3	240.0	4.00	2.02
4	180.0	3.00	1.88
5	300.0	5.00	1.16
6	480.0	8.00	1.03
7	660.0	11.00	0.99
8	540.0	9.00	0.83
9	420.0	7.00	0.65
10	360.0	6.00	0.62

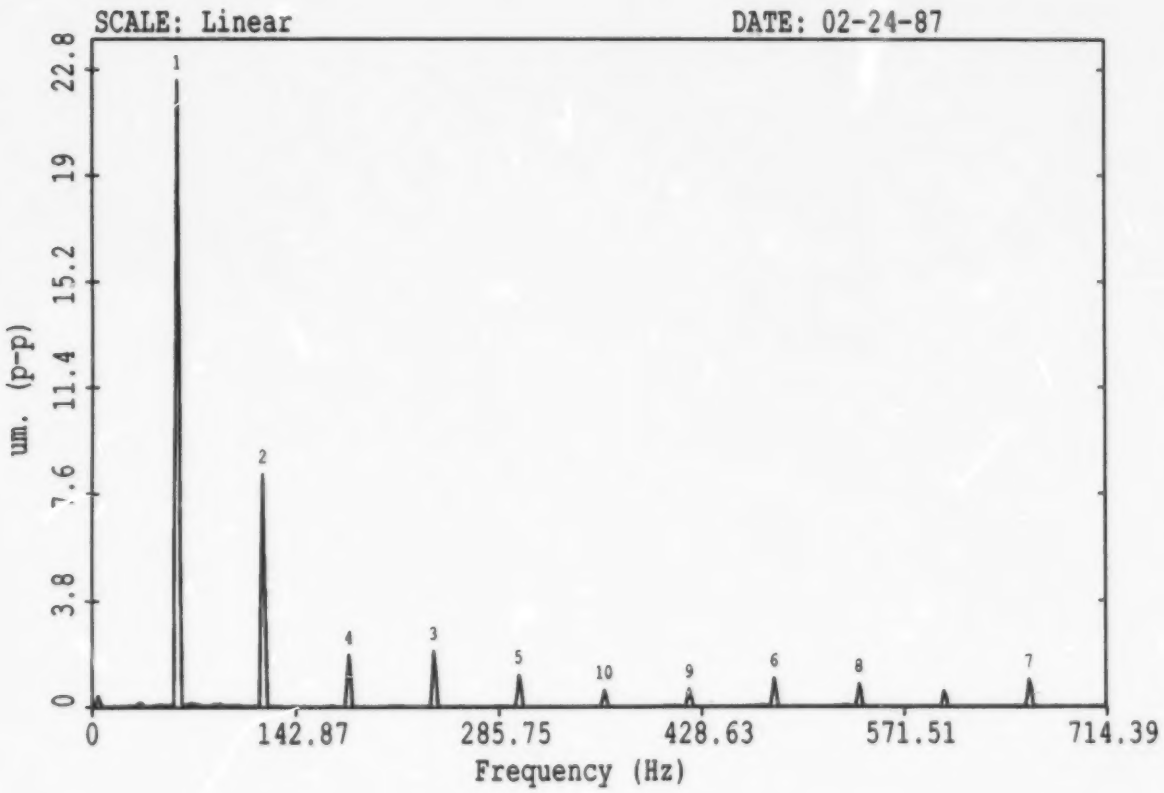


FIGURE 56
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	17.87
2	120.0	2.00	8.41
3	240.0	4.00	2.05
4	300.0	5.00	1.16
5	540.0	9.00	1.16
6	660.0	11.00	1.03
7	180.0	3.00	0.90
8	420.0	7.00	0.85
9	480.0	8.00	0.85
10	360.0	6.00	0.52

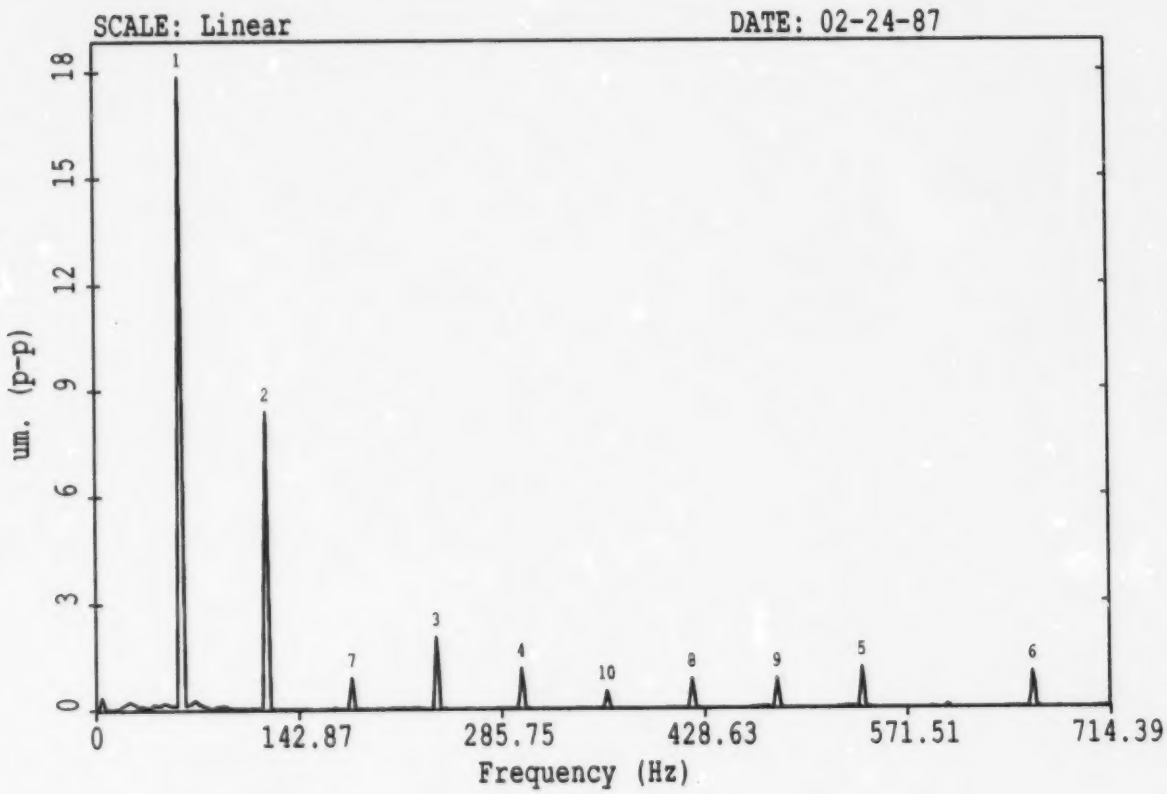


FIGURE 57
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	15.54
2	540.0	9.00	3.16
3	180.0	3.00	2.92
4	600.0	10.00	2.58
5	660.0	11.00	2.38
6	480.0	8.00	2.37
7	120.0	2.00	1.93
8	420.0	7.00	1.91
9	360.0	6.00	1.61
10	240.0	4.00	0.80

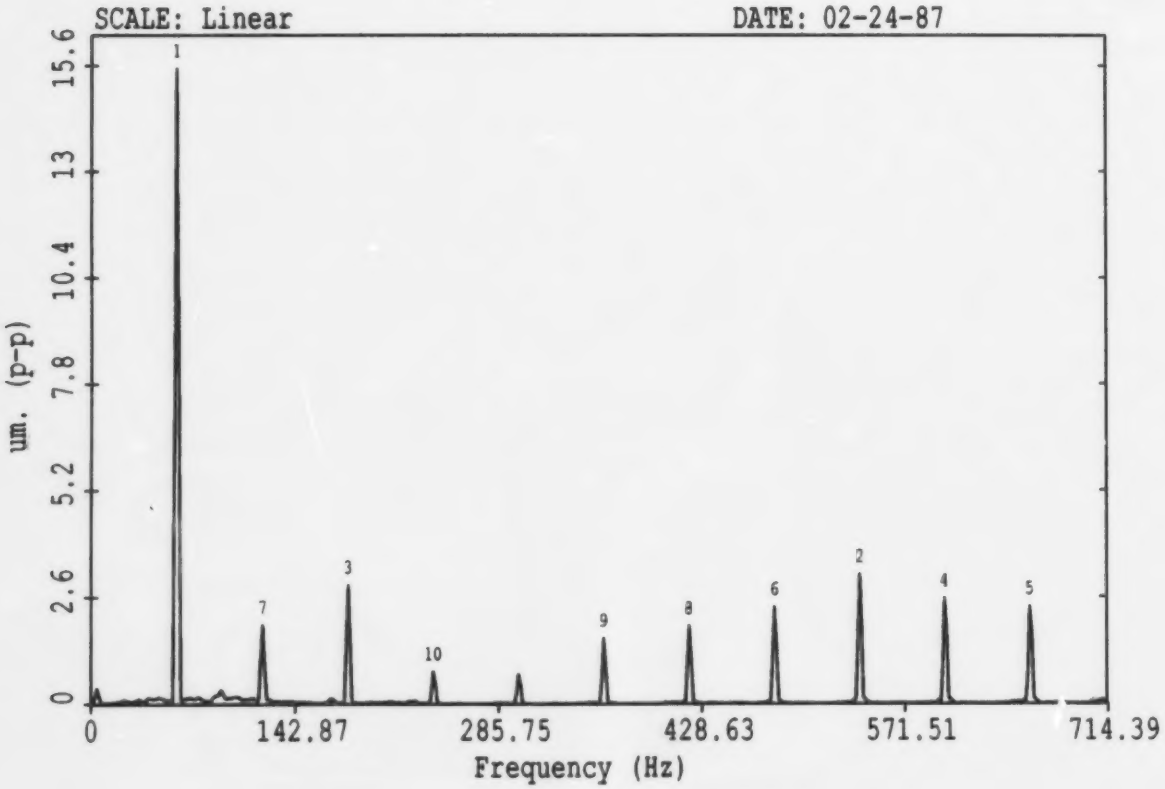


FIGURE 58
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	18.05
2	540.0	9.00	2.97
3	180.0	3.00	2.82
4	600.0	10.00	2.56
5	660.0	11.00	2.25
6	480.0	8.00	2.23
7	420.0	7.00	2.10
8	360.0	6.00	1.78
9	120.0	2.00	1.13
10	300.0	5.00	1.03

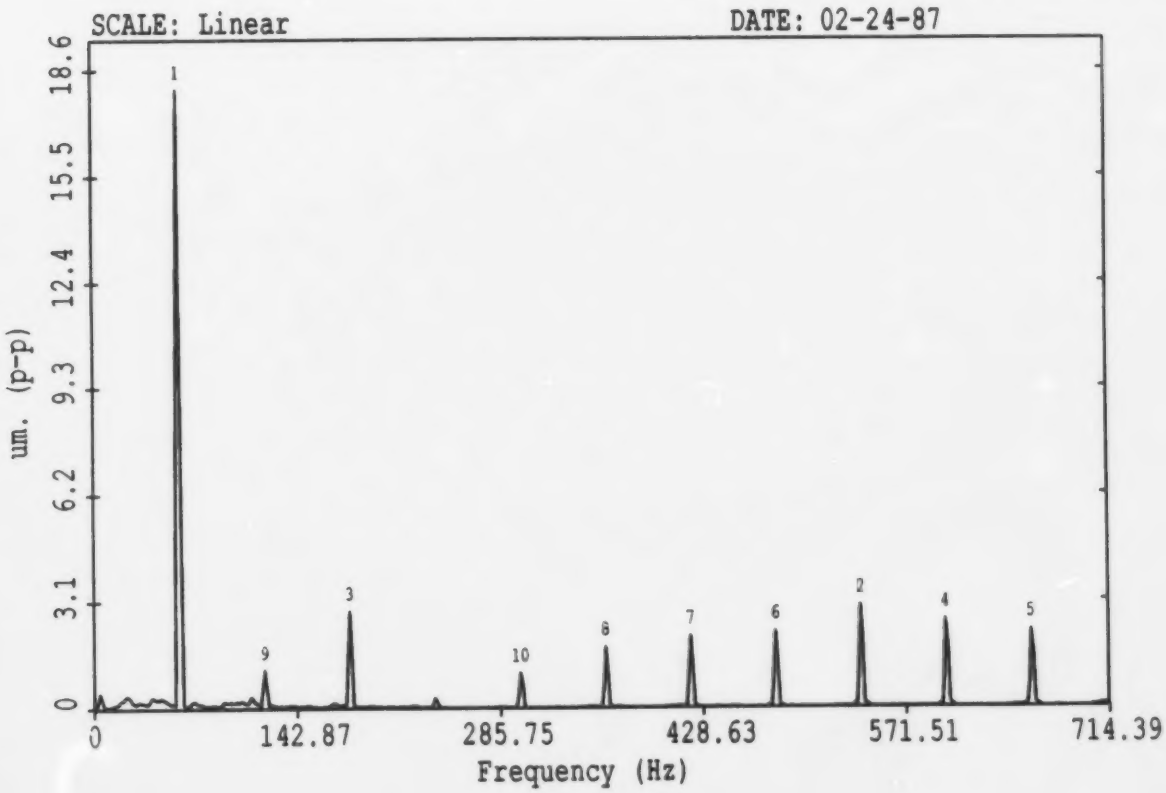


FIGURE 59

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	21.58
2	120.0	2.00	8.38
3	240.0	4.00	1.97
4	180.0	3.00	1.80
5	300.0	5.00	1.17
6	480.0	8.00	1.03
7	660.0	11.00	1.02
8	540.0	9.00	0.86
9	420.0	7.00	0.68
10	360.0	6.00	0.63

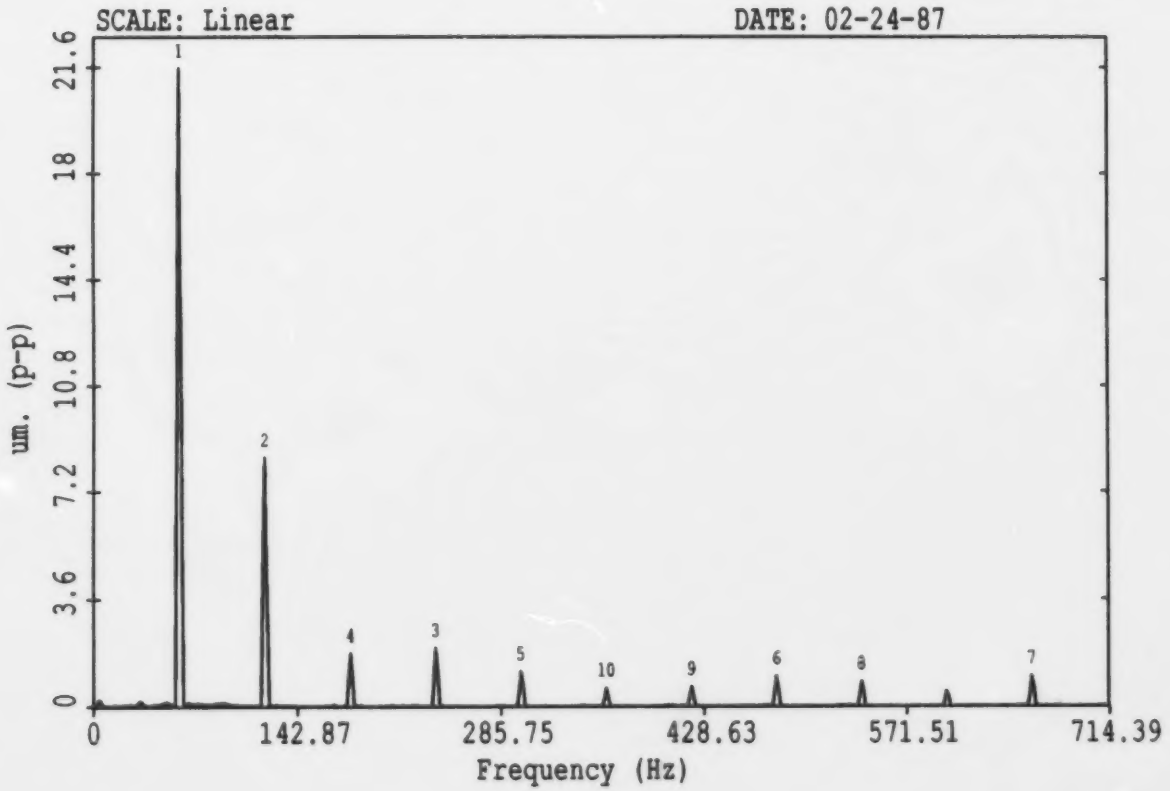


FIGURE 60

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	16.45
2	120.0	2.00	8.37
3	240.0	4.00	2.08
4	540.0	9.00	1.19
5	300.0	5.00	1.17
6	660.0	11.00	1.05
7	420.0	7.00	0.88
8	480.0	8.00	0.85
9	180.0	3.00	0.81
10	360.0	6.00	0.52

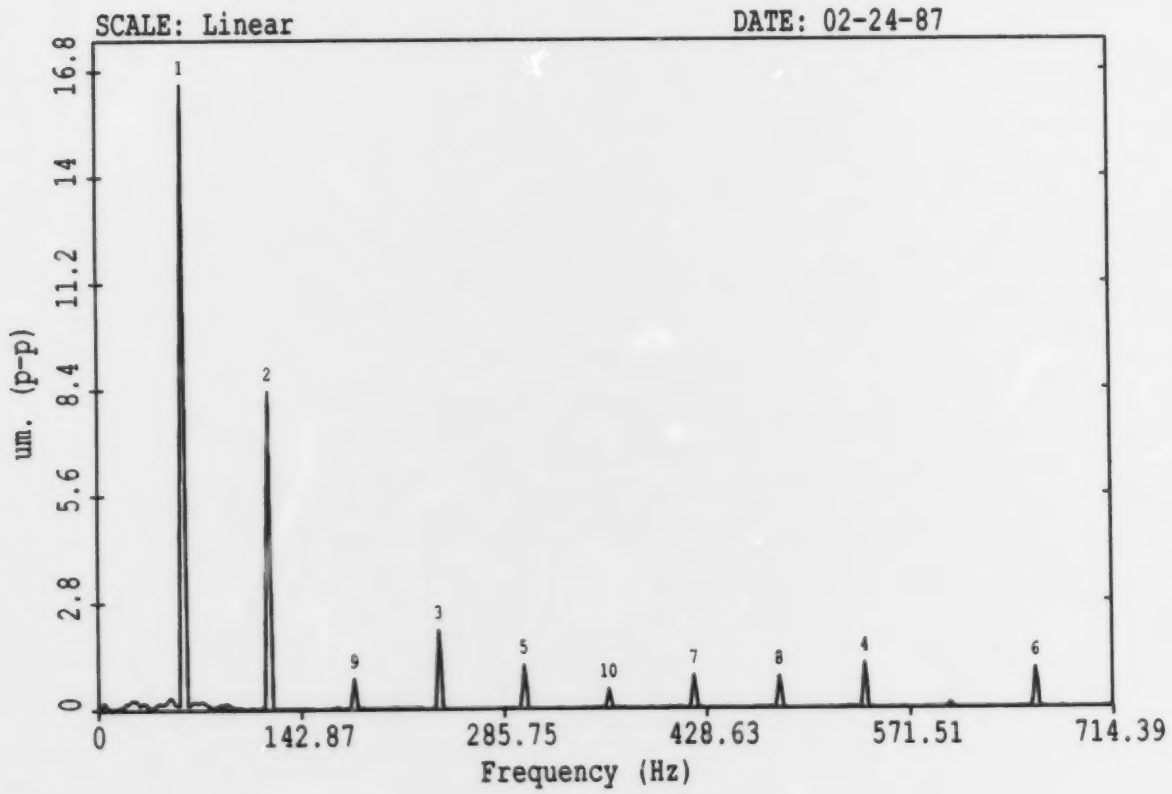


FIGURE 61
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	14.36
2	540.0	9.00	3.17
3	180.0	3.00	2.95
4	600.0	10.00	2.62
5	660.0	11.00	2.39
6	480.0	8.00	2.38
7	120.0	2.00	2.08
8	420.0	7.00	1.94
9	360.0	6.00	1.63
10	300.0	5.00	0.77

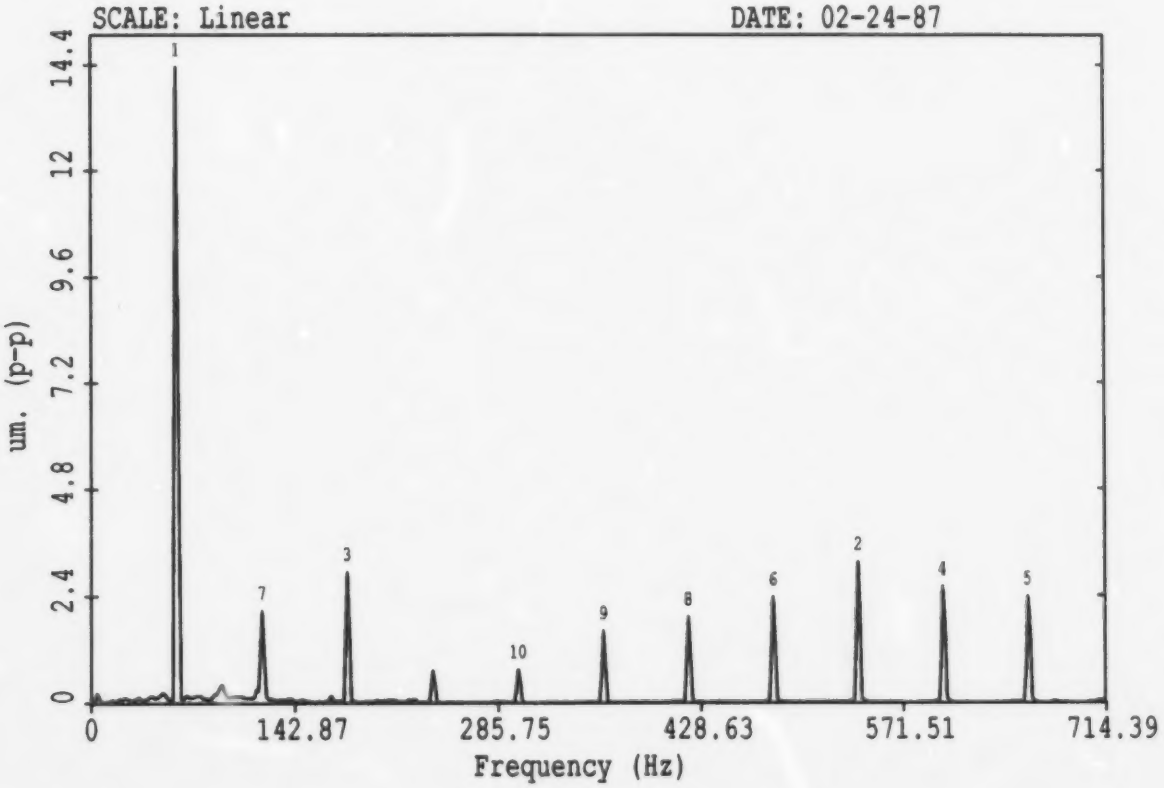


FIGURE 62
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 15 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	16.27
2	540.0	9.00	2.97
3	180.0	3.00	2.90
4	600.0	10.00	2.56
5	660.0	11.00	2.26
6	480.0	8.00	2.21
7	420.0	7.00	2.12
8	360.0	6.00	1.78
9	120.0	2.00	1.39
10	300.0	5.00	1.01

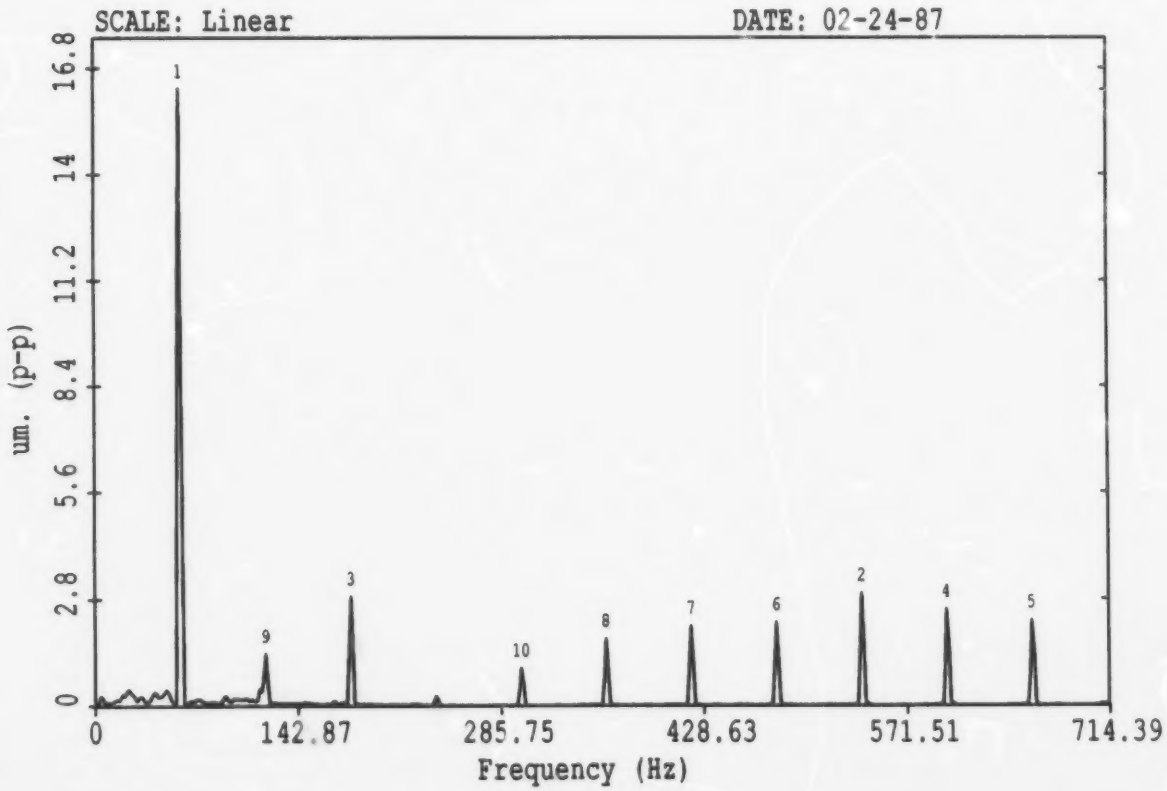


FIGURE 63

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	20.69
2	120.0	2.00	8.28
3	240.0	4.00	1.90
4	180.0	3.00	1.83
5	300.0	5.00	1.14
6	660.0	11.00	1.03
7	480.0	8.00	1.03
8	540.0	9.00	0.90
9	420.0	7.00	0.67
10	360.0	6.00	0.61

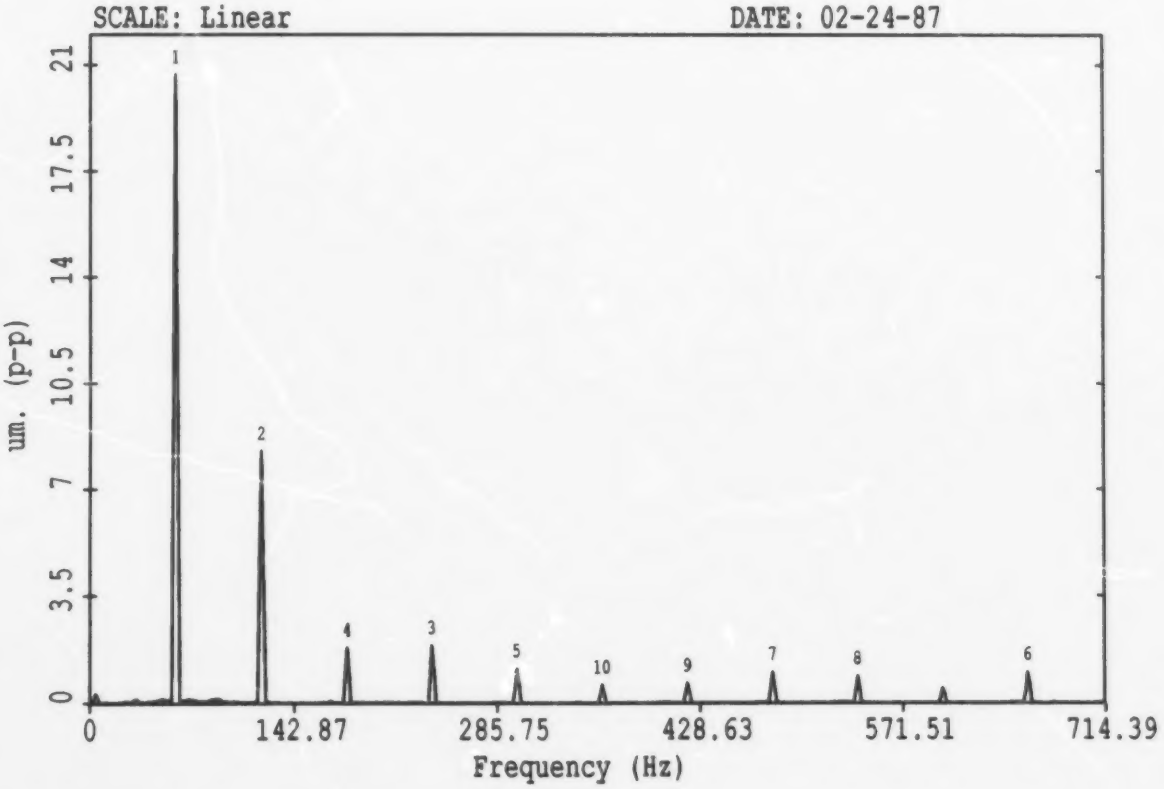


FIGURE 64
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	15.08
2	120.0	2.00	8.32
3	240.0	4.00	2.06
4	540.0	9.00	1.18
5	300.0	5.00	1.13
6	660.0	11.00	1.05
7	420.0	7.00	0.89
8	480.0	8.00	0.84
9	180.0	3.00	0.76
10	360.0	6.00	0.50

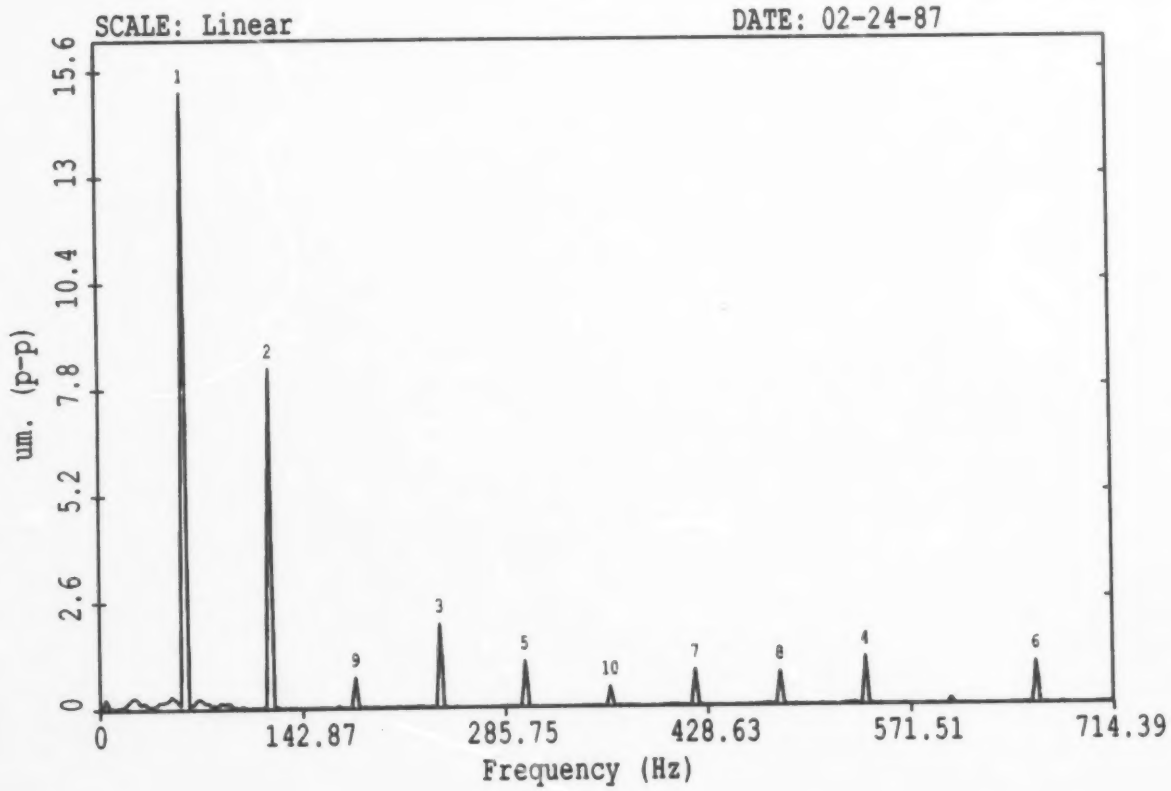


FIGURE 65
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	13.14
2	540.0	9.00	3.18
3	180.0	3.00	3.03
4	600.0	10.00	2.62
5	660.0	11.00	2.39
6	480.0	8.00	2.35
7	120.0	2.00	2.13
8	420.0	7.00	1.94
9	360.0	6.00	1.65
10	300.0	5.00	0.80

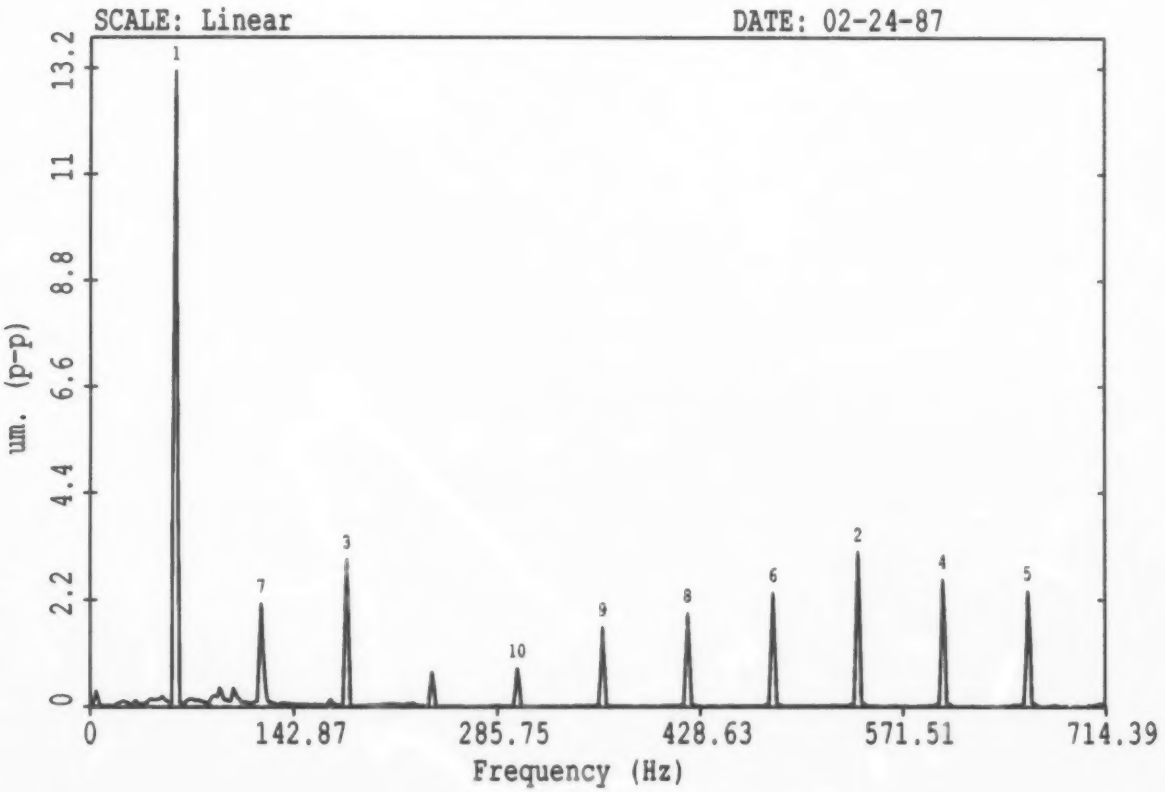


FIGURE 66

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	14.84
2	180.0	3.00	2.96
3	540.0	9.00	2.93
4	600.0	10.00	2.56
5	660.0	11.00	2.26
6	480.0	8.00	2.18
7	420.0	7.00	2.15
8	360.0	6.00	1.75
9	120.0	2.00	1.62
10	300.0	5.00	1.01

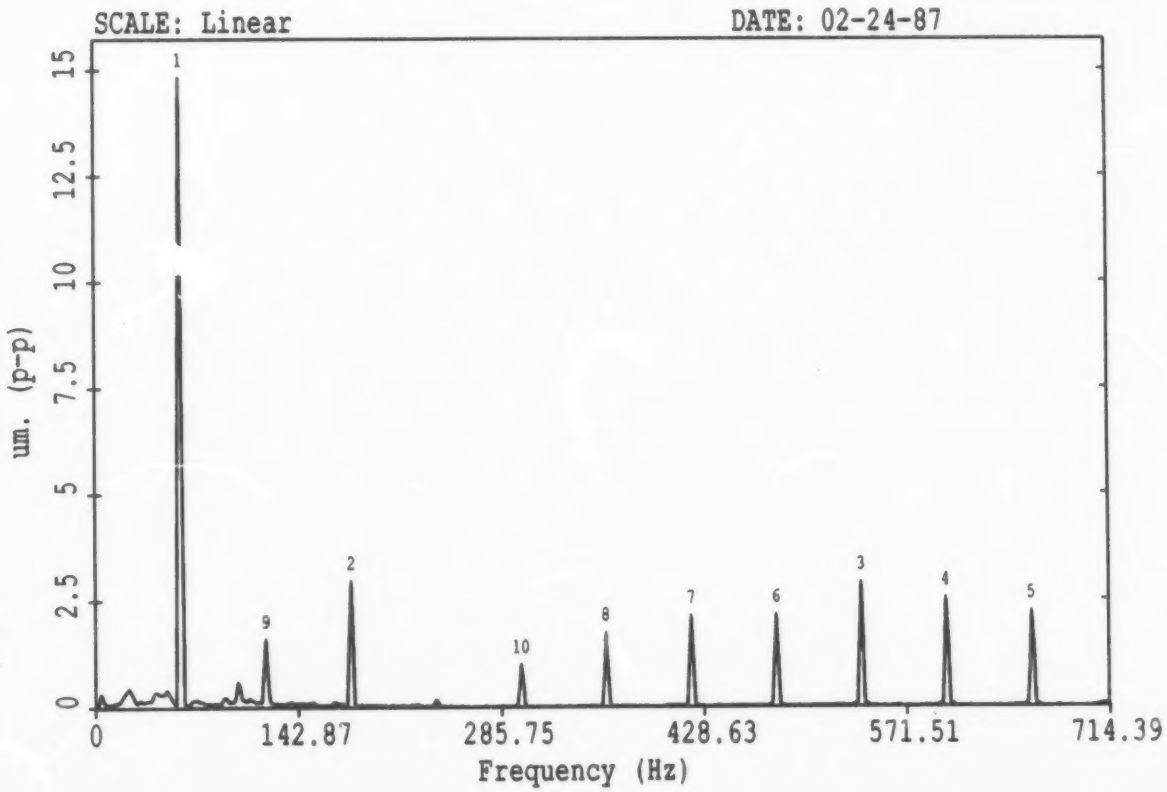


FIGURE 67
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	19.90
2	120.0	2.00	8.22
3	180.0	3.00	1.90
4	240.0	4.00	1.83
5	300.0	5.00	1.13
6	480.0	8.00	1.00
7	660.0	11.00	0.96
8	540.0	9.00	0.84
9	420.0	7.00	0.64
10	360.0	6.00	0.60

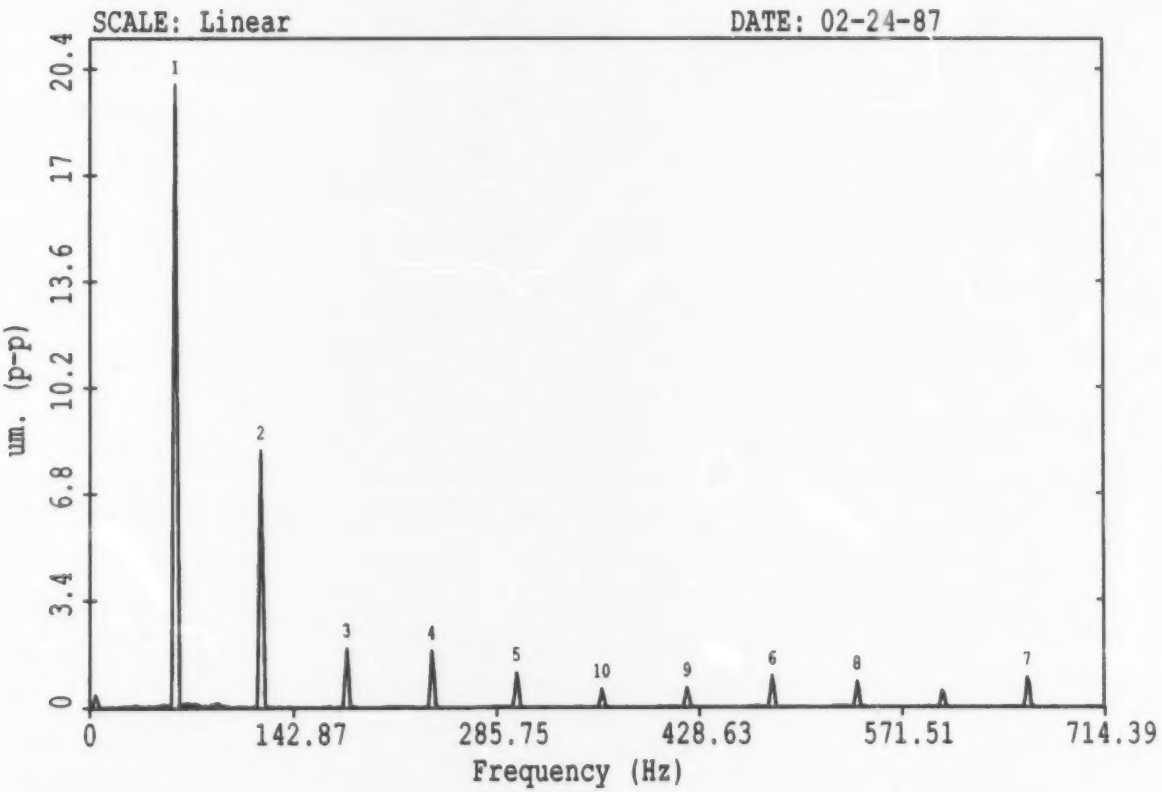


FIGURE 68

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	15.75
2	120.0	2.00	8.14
3	240.0	4.00	2.07
4	540.0	9.00	1.13
5	300.0	5.00	1.09
6	660.0	11.00	1.00
7	420.0	7.00	0.85
8	480.0	8.00	0.83
9	180.0	3.00	0.82
10	360.0	6.00	0.50

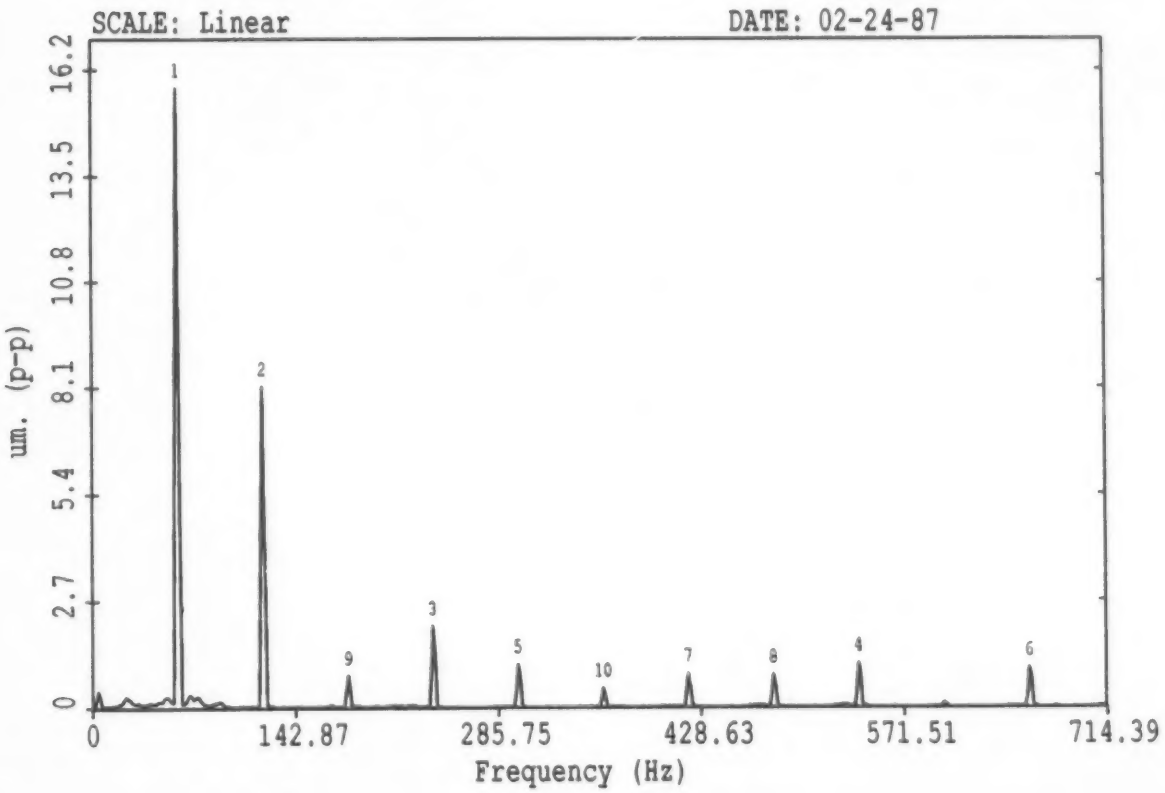


FIGURE 69
88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 2[illegible] MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	13.75
2	180.0	3.00	3.15
3	540.0	9.00	3.10
4	600.0	10.00	2.50
5	480.0	8.00	2.31
6	660.0	11.00	2.29
7	120.0	2.00	1.99
8	420.0	7.00	1.87
9	360.0	6.00	1.62
10	300.0	5.00	0.74

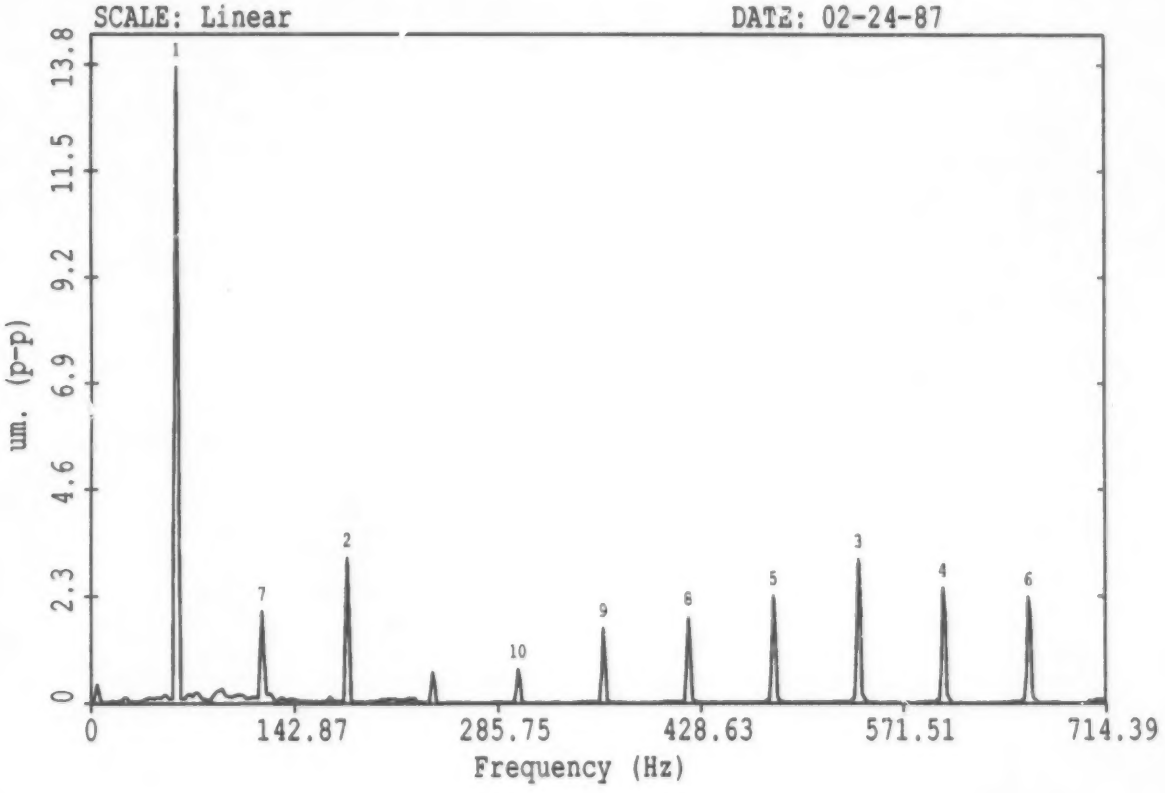


FIGURE 70

88-241

Darlington GS Standby Generator #1 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	15.70
2	540.0	9.00	2.87
3	180.0	3.00	2.79
4	600.0	10.00	2.46
5	660.0	11.00	2.17
6	480.0	8.00	2.16
7	420.0	7.00	2.09
8	120.0	2.00	1.79
9	360.0	6.00	1.70
10	300.0	5.00	0.94

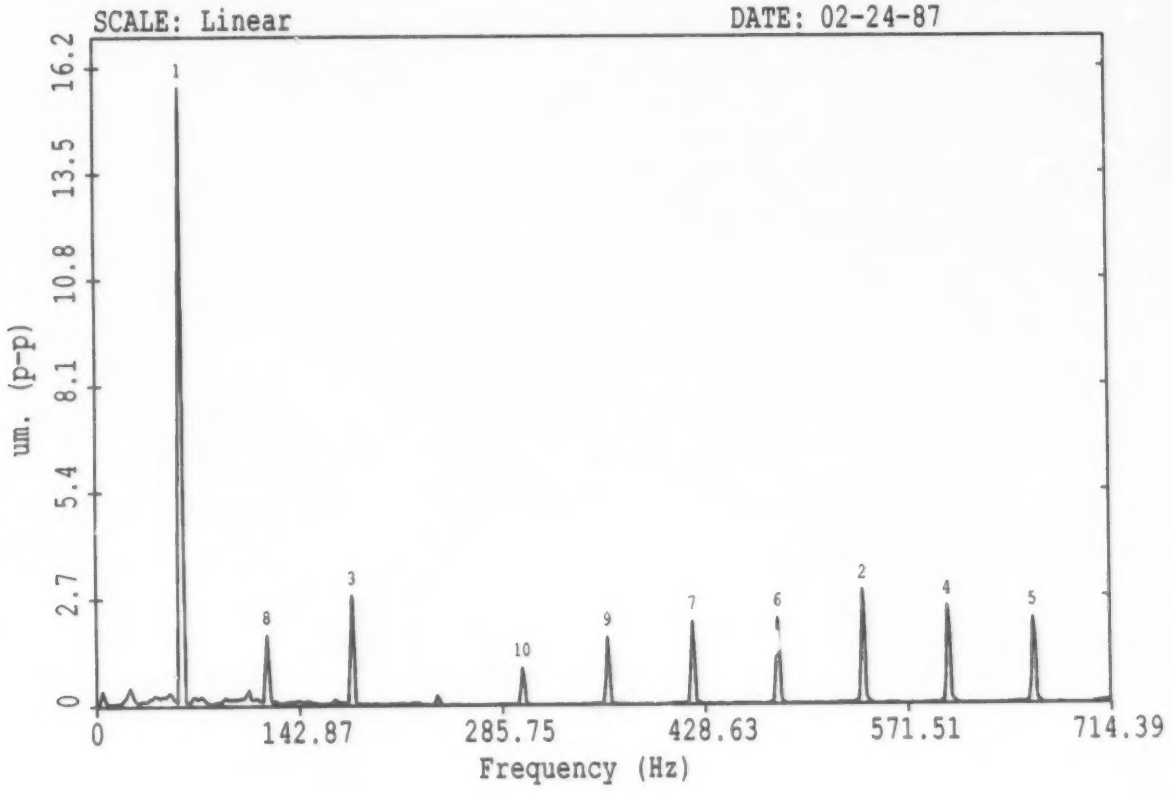


FIGURE 71
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	85.03
2	120.0	2.00	34.29
3	16.7	0.28	12.42
4	180.0	3.00	12.14
5	30.7	0.51	8.86
6	300.0	5.00	7.01
7	40.5	0.67	6.98
8	37.7	0.63	5.87
9	240.0	4.00	5.52
10	360.0	6.00	4.24

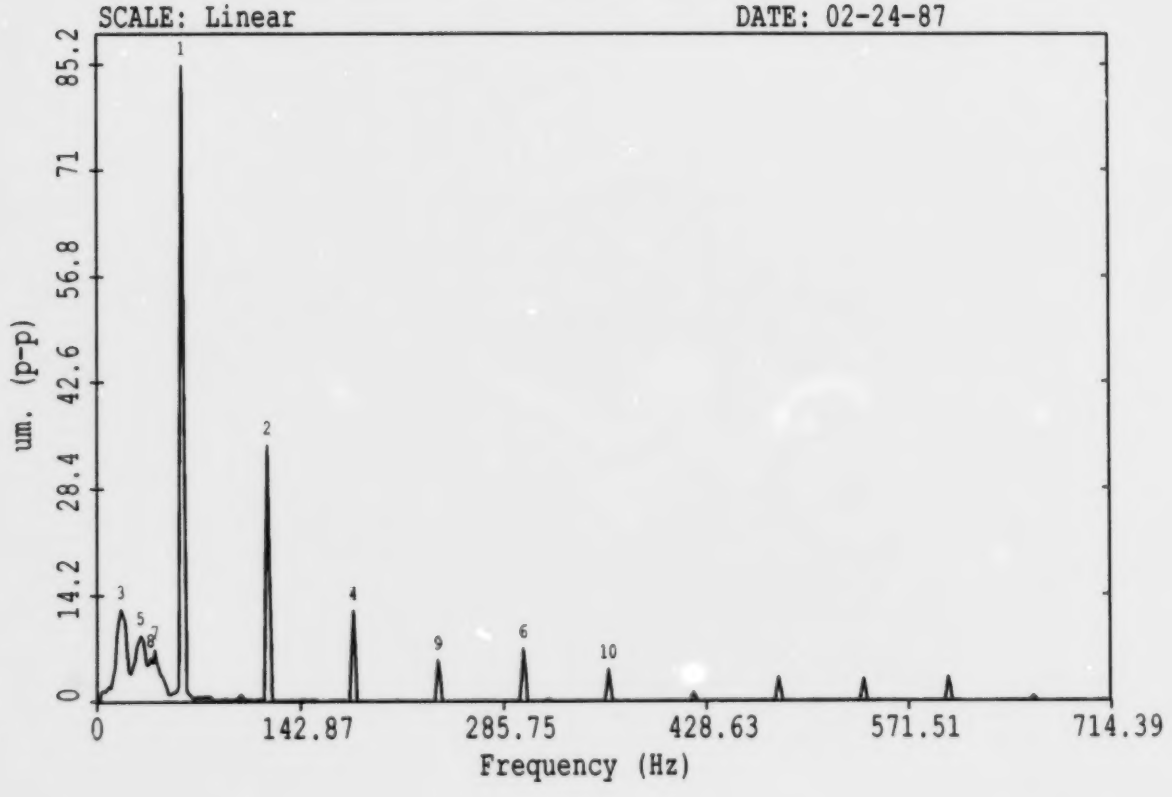


FIGURE 72
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	73.13
2	120.0	2.00	36.73
3	180.0	3.00	9.38
4	300.0	5.00	7.24
5	240.0	4.00	5.85
6	40.5	0.67	5.38
7	360.0	6.00	4.18
8	16.7	0.28	3.89
9	46.0	0.77	3.89
10	480.0	8.00	3.14

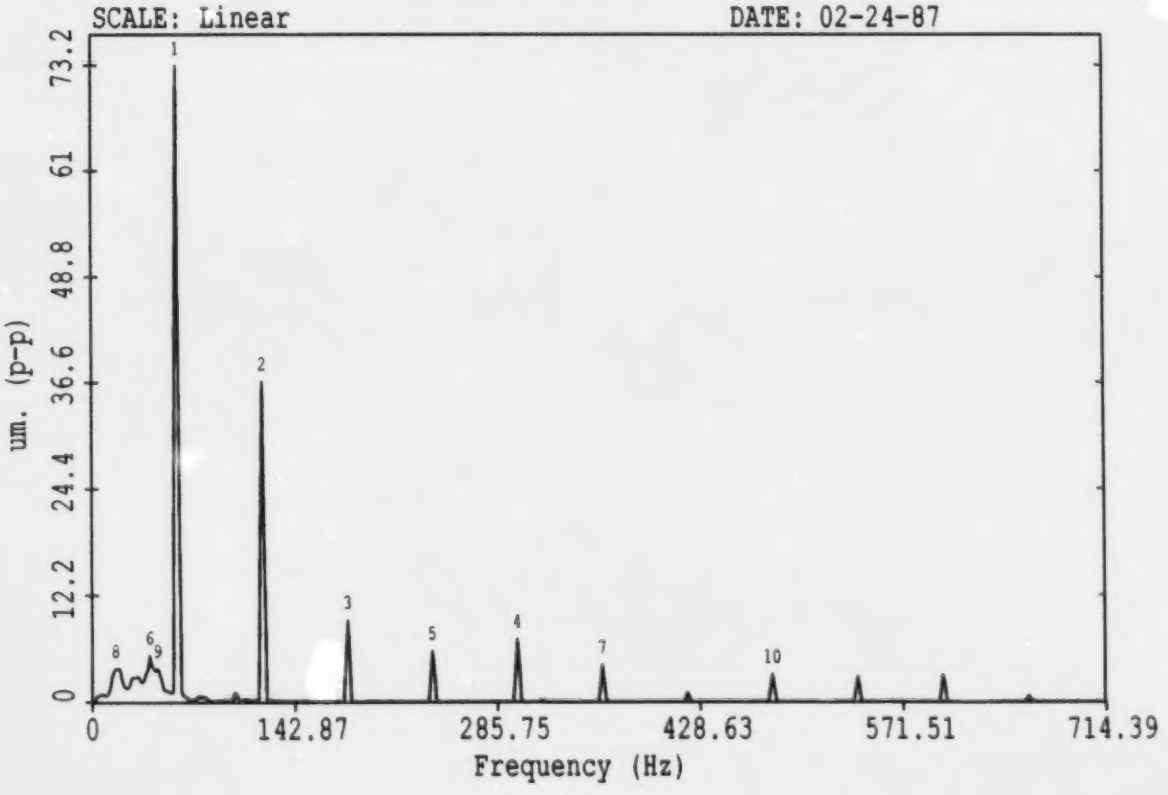


FIGURE 73
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	19.5	0.33	4.73
2	120.0	2.00	4.73
3	60.0	1.00	4.59
4	180.0	3.00	2.47
5	240.0	4.00	1.51
6	29.3	0.49	1.49
7	480.0	8.00	1.19
8	420.0	7.00	0.83
9	43.3	0.72	0.79
10	47.4	0.79	0.78

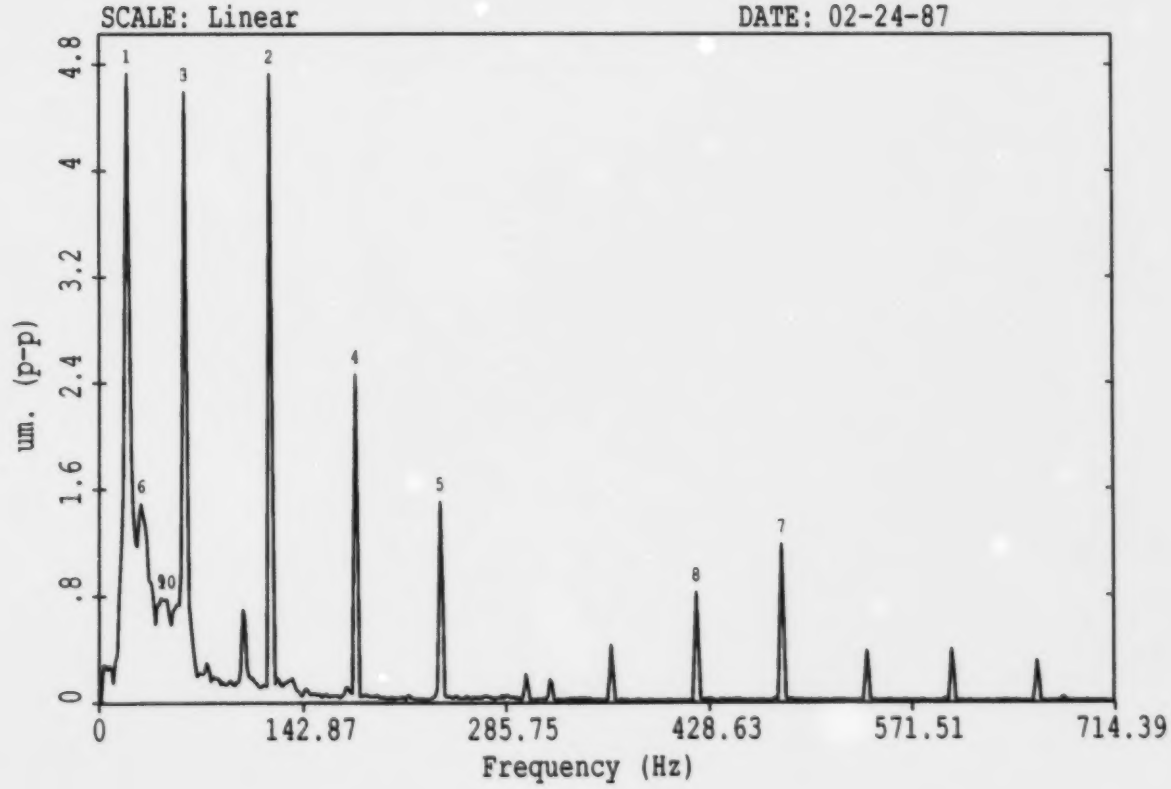


FIGURE 74

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	17.04
2	19.5	0.33	12.61
3	120.0	2.00	7.09
4	29.3	0.49	4.40
5	53.0	0.88	2.13
6	43.3	0.72	2.06
7	40.5	0.67	1.97
8	240.0	4.00	1.49
9	480.0	8.00	1.23
10	180.0	3.00	1.16

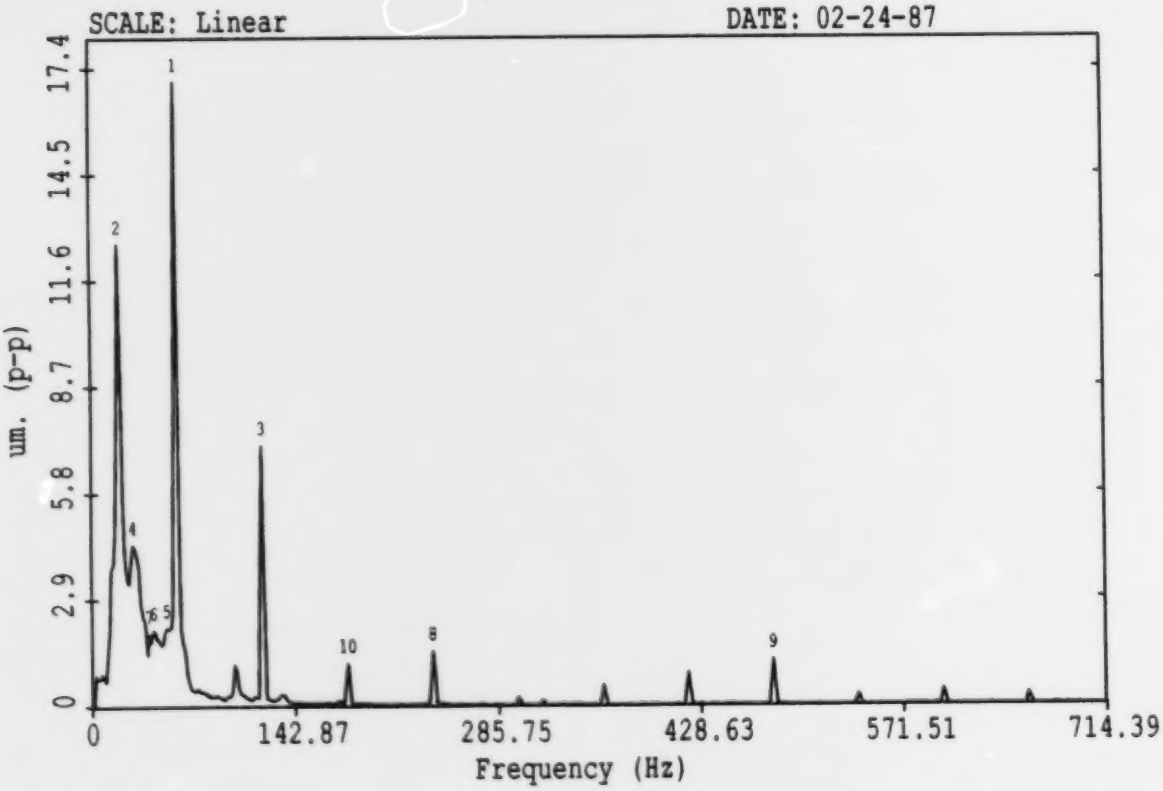


FIGURE 75

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	84.47
2	120.0	2.00	34.29
3	180.0	3.00	12.46
4	15.3	0.26	11.34
5	19.5	0.33	9.16
6	300.0	5.00	7.01
7	30.7	0.51	6.52
8	40.5	0.67	6.11
9	240.0	4.00	5.51
10	360.0	6.00	4.17

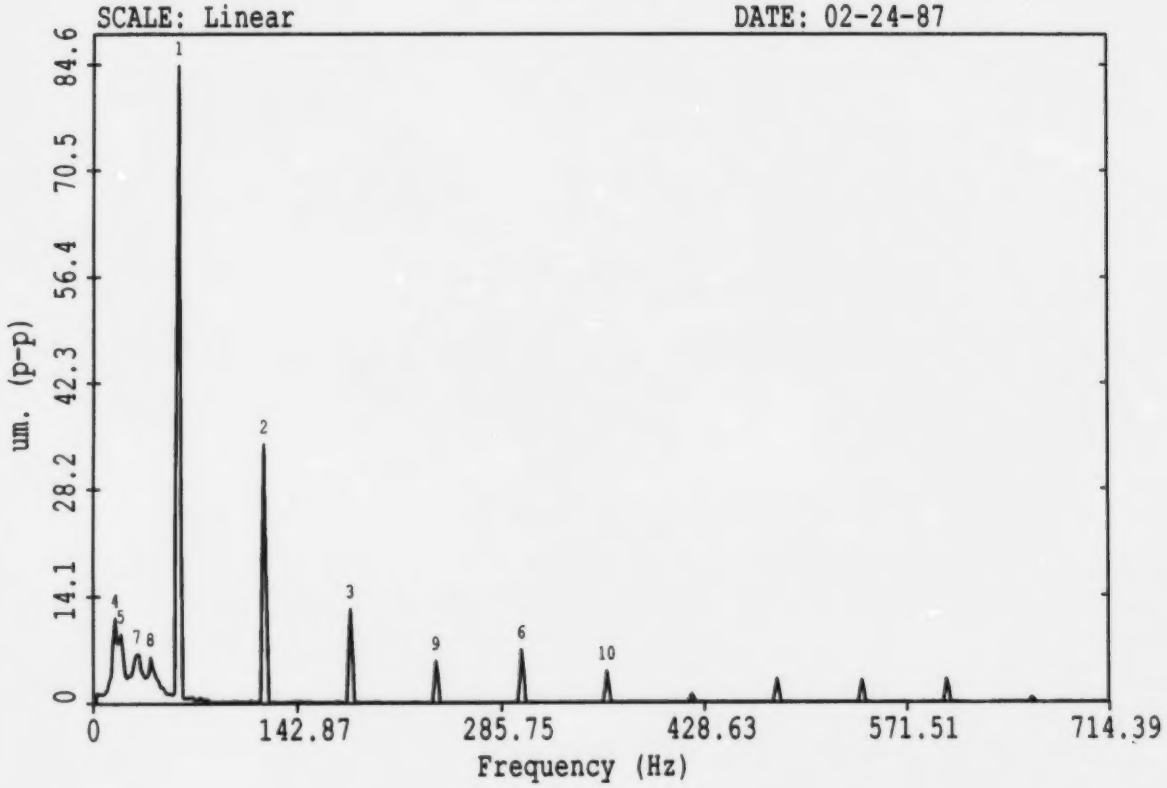


FIGURE 76
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	72.57
2	120.0	2.00	36.79
3	180.0	3.00	8.80
4	300.0	5.00	7.20
5	240.0	4.00	5.72
6	15.3	0.26	4.76
7	40.5	0.67	4.14
8	360.0	6.00	4.14
9	19.5	0.33	4.12
10	480.0	8.00	3.13

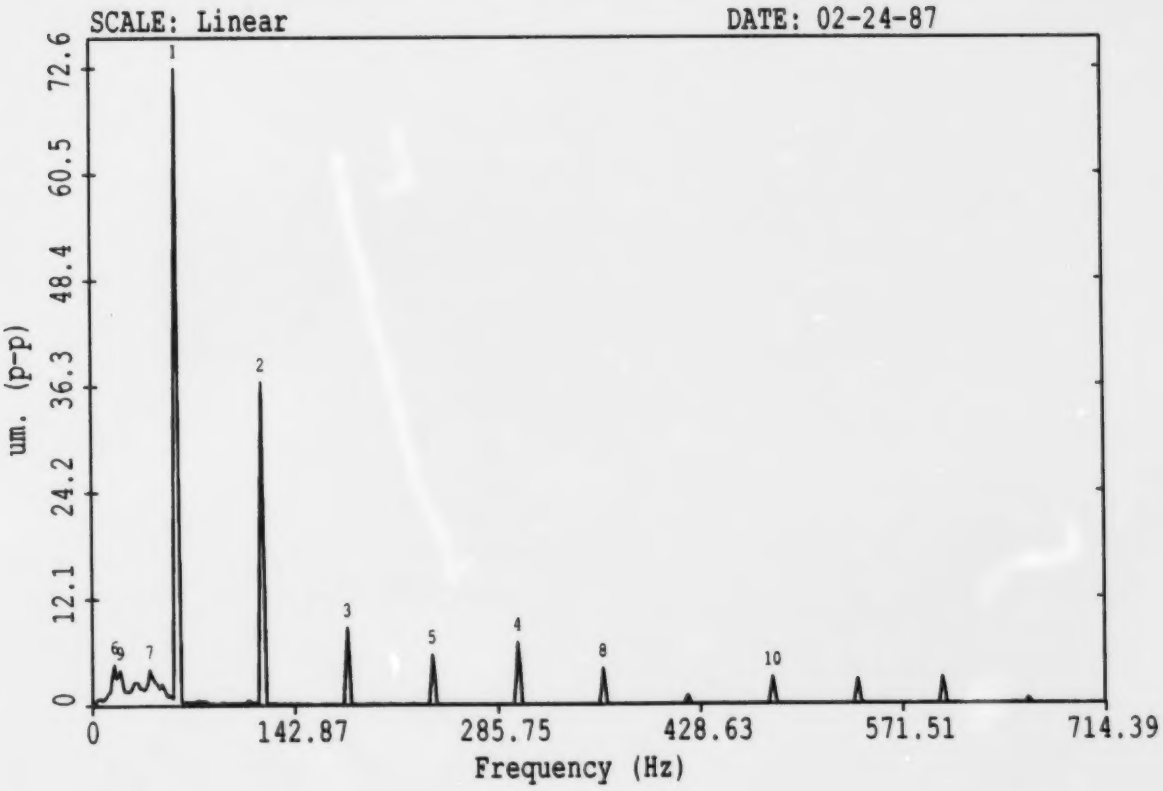


FIGURE 77
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	5.15
2	19.5	0.33	5.06
3	120.0	2.00	4.52
4	180.0	3.00	2.53
5	240.0	4.00	1.56
6	480.0	8.00	1.19
7	30.7	0.51	1.10
8	15.3	0.26	1.04
9	53.0	0.88	0.93
10	50.2	0.84	0.90

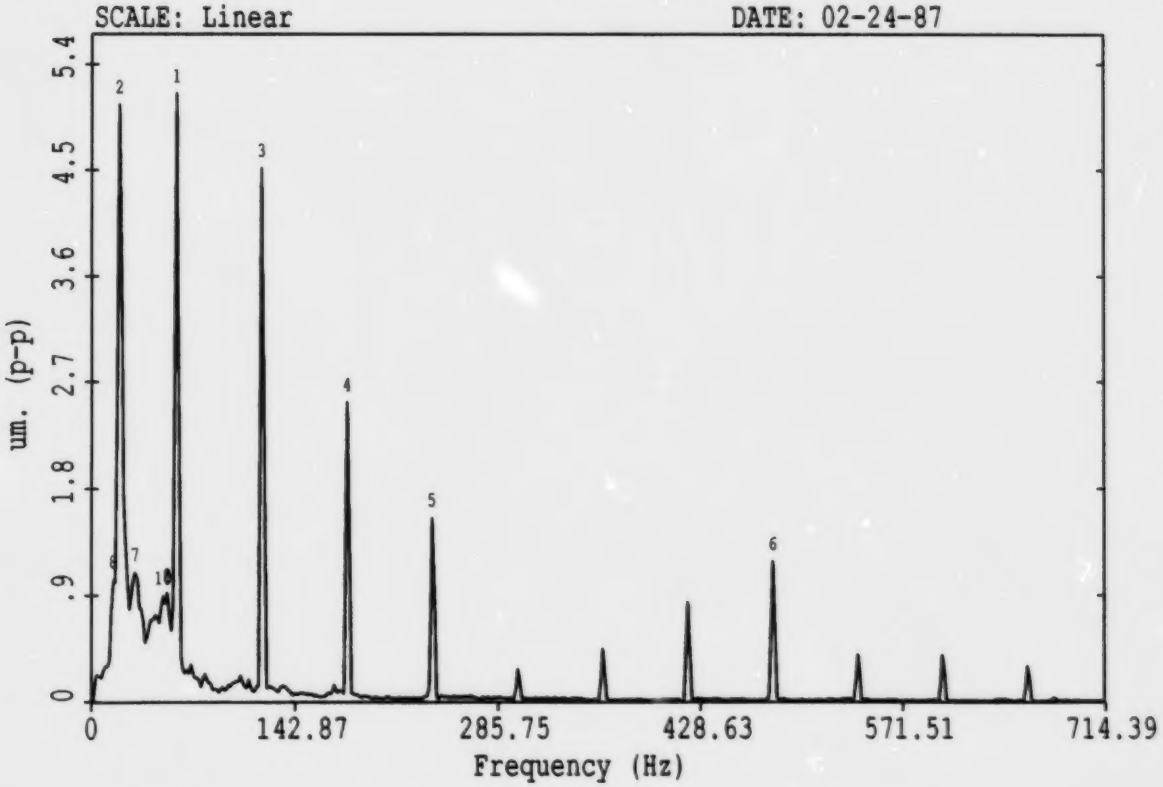


FIGURE 78
88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	17.18
2	19.5	0.33	14.94
3	120.0	2.00	6.90
4	15.3	0.26	5.41
5	30.7	0.51	3.34
6	53.0	0.88	2.73
7	34.9	0.58	2.51
8	240.0	4.00	1.58
9	39.1	0.65	1.36
10	480.0	8.00	1.22

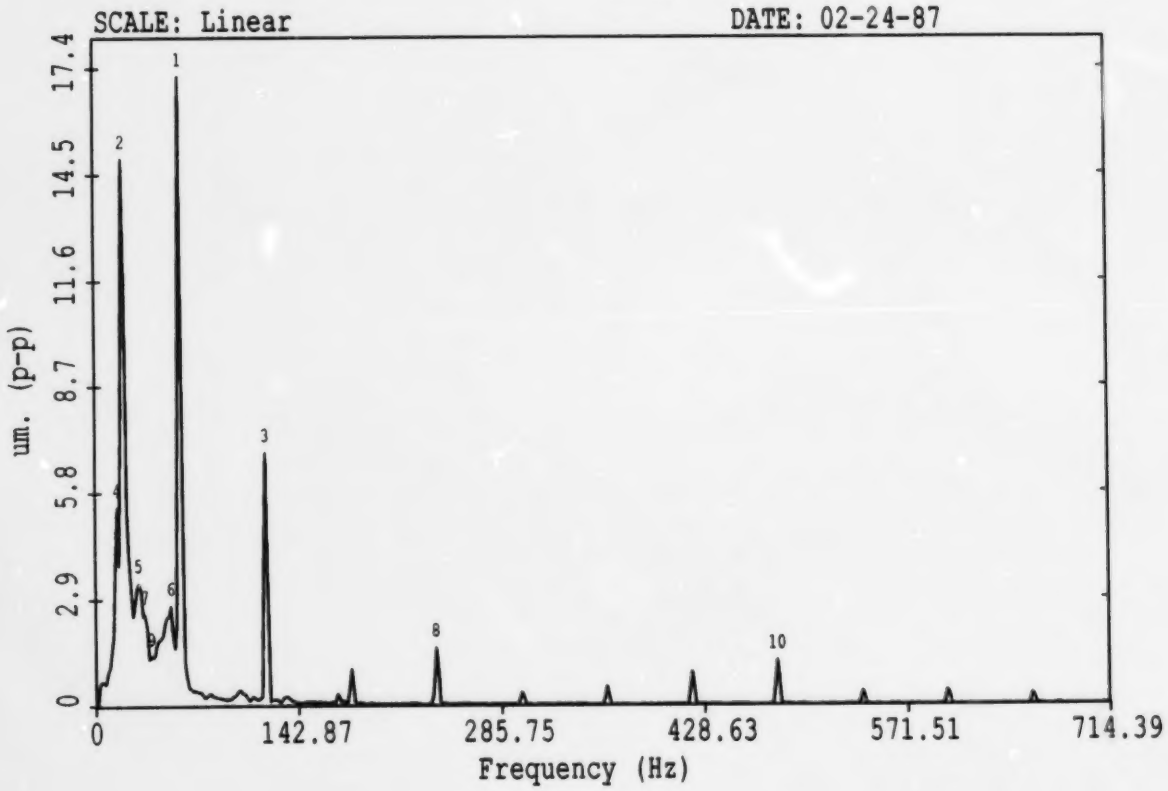


FIGURE 79

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	83.12
2	120.0	2.00	34.29
3	180.0	3.00	12.71
4	15.3	0.26	7.90
5	32.1	0.53	7.45
6	300.0	5.00	7.06
7	19.5	0.33	5.49
8	240.0	4.00	5.43
9	41.9	0.70	4.69
10	26.5	0.44	4.16

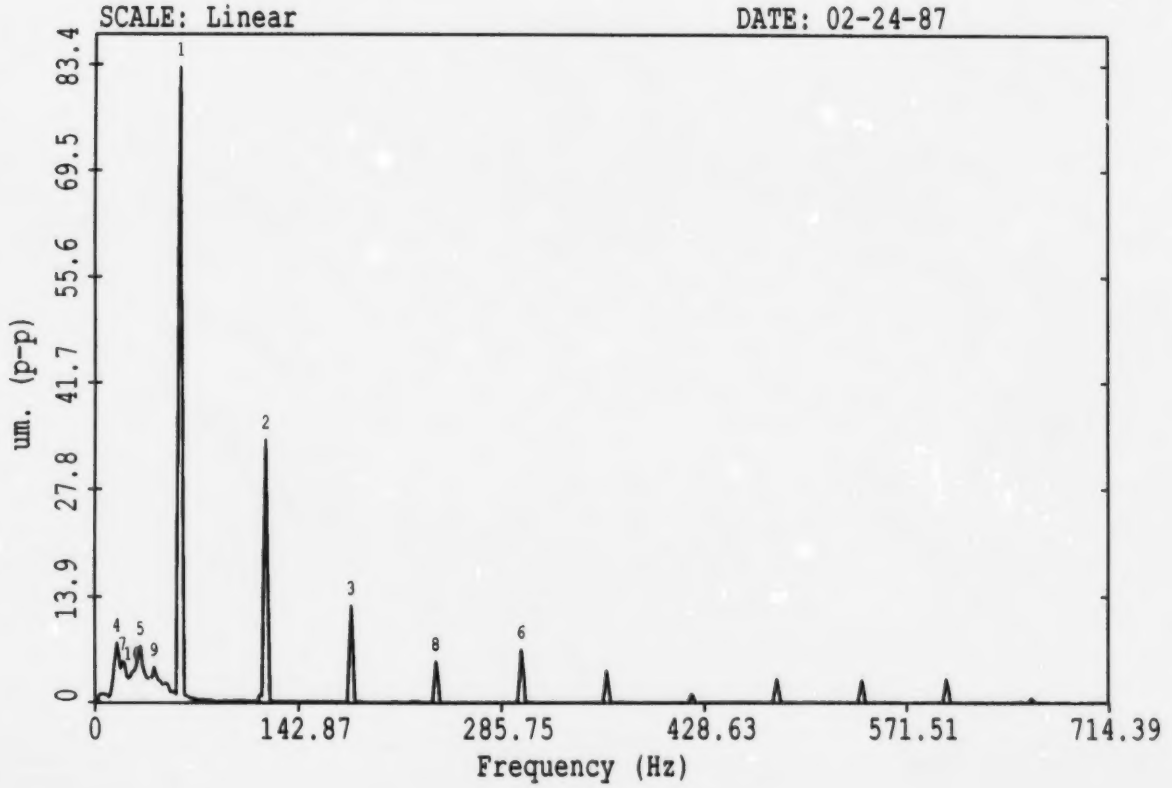


FIGURE 80

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	70.65
2	120.0	2.00	36.92
3	180.0	3.00	8.49
4	300.0	5.00	7.21
5	240.0	4.00	5.68
6	360.0	6.00	4.12
7	15.3	0.26	3.85
8	32.1	0.53	3.31
9	480.0	8.00	3.14
10	41.9	0.70	3.10

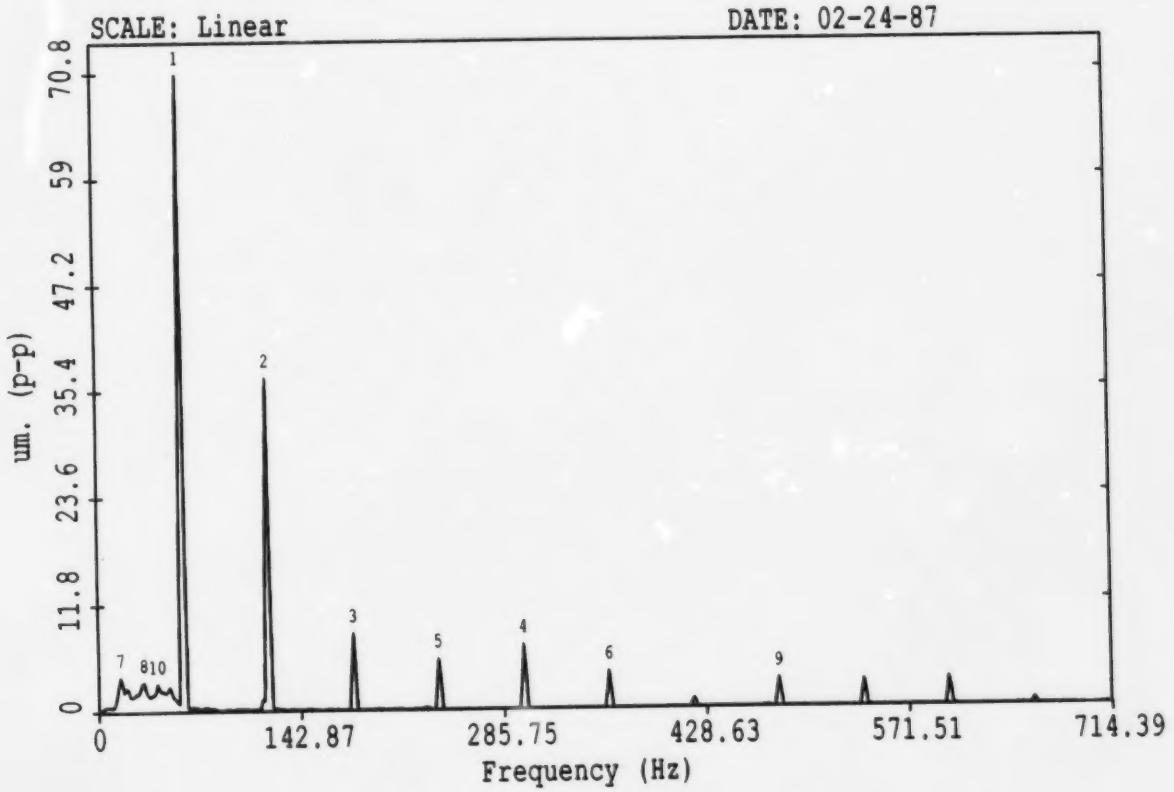


FIGURE 81

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	4.90
2	120.0	2.00	4.37
3	20.9	0.35	3.95
4	180.0	3.00	2.72
5	240.0	4.00	1.59
6	32.1	0.53	1.48
7	480.0	8.00	1.20
8	15.3	0.26	1.01
9	53.0	0.88	0.93
10	420.0	7.00	0.82

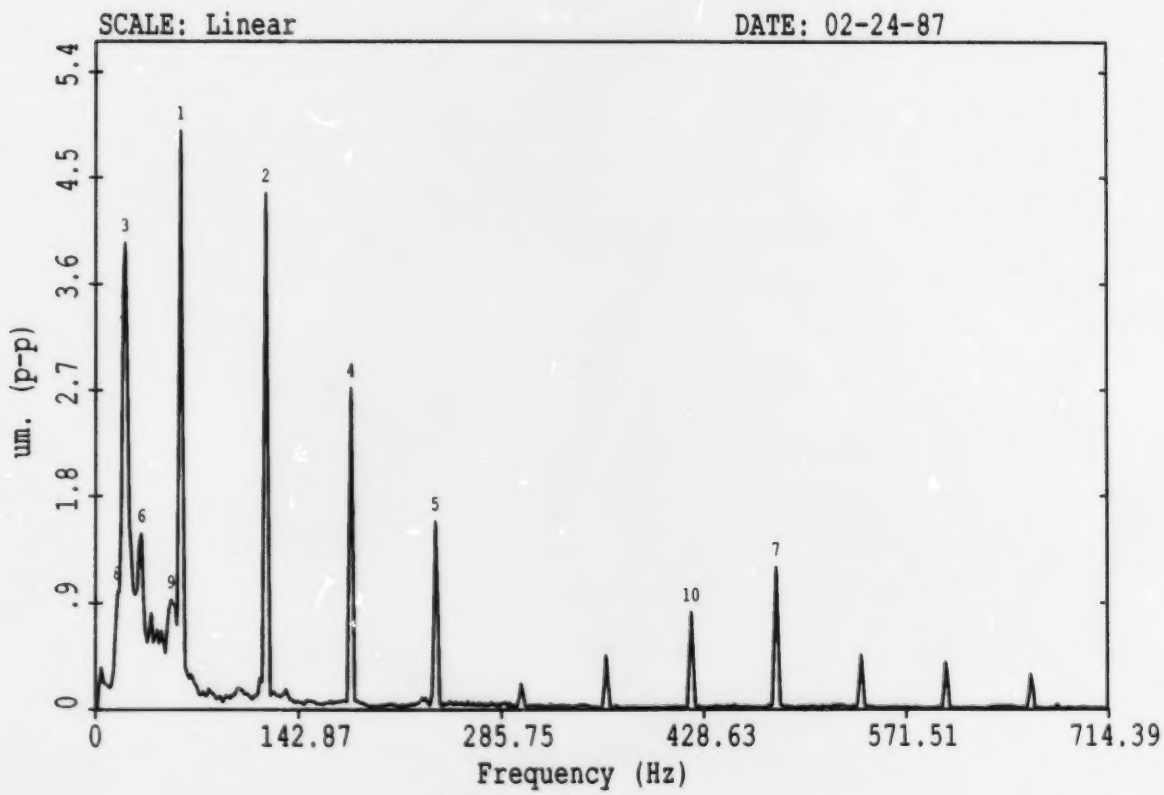


FIGURE 82

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	14.54
2	20.9	0.35	12.07
3	120.0	2.00	6.72
4	15.3	0.26	5.60
5	32.1	0.53	4.52
6	53.0	0.88	2.58
7	39.1	0.65	1.86
8	240.0	4.00	1.63
9	46.0	0.77	1.62
10	43.3	0.72	1.55

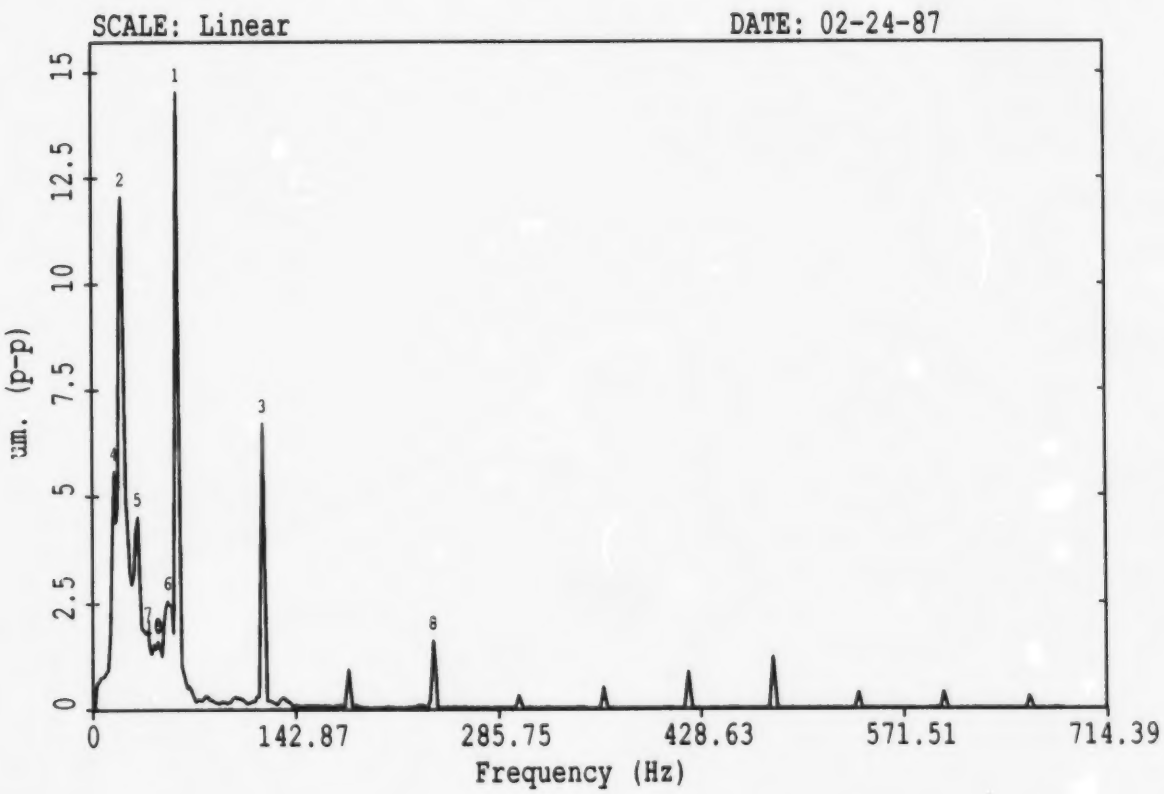


FIGURE 83

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	82.18
2	120.0	2.00	34.21
3	180.0	3.00	13.04
4	300.0	5.00	7.00
5	32.1	0.53	6.09
6	240.0	4.00	5.35
7	16.7	0.28	5.29
8	40.5	0.67	4.96
9	360.0	6.00	4.15
10	26.5	0.44	3.52

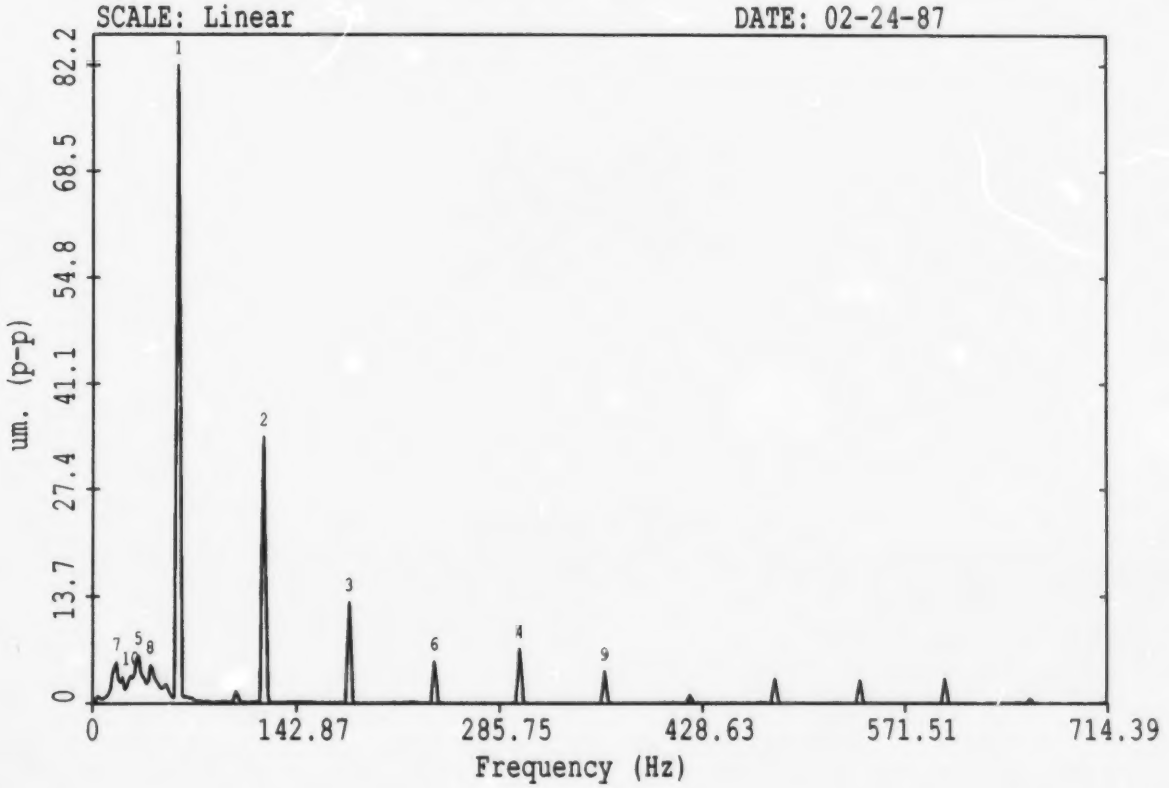


FIGURE 84

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	67.84
2	120.0	2.00	37.01
3	180.0	3.00	8.09
4	300.0	5.00	7.20
5	240.0	4.00	5.65
6	360.0	6.00	4.11
7	480.0	8.00	3.15
8	600.0	10.00	3.07
9	40.5	0.67	2.94
10	540.0	9.00	2.92

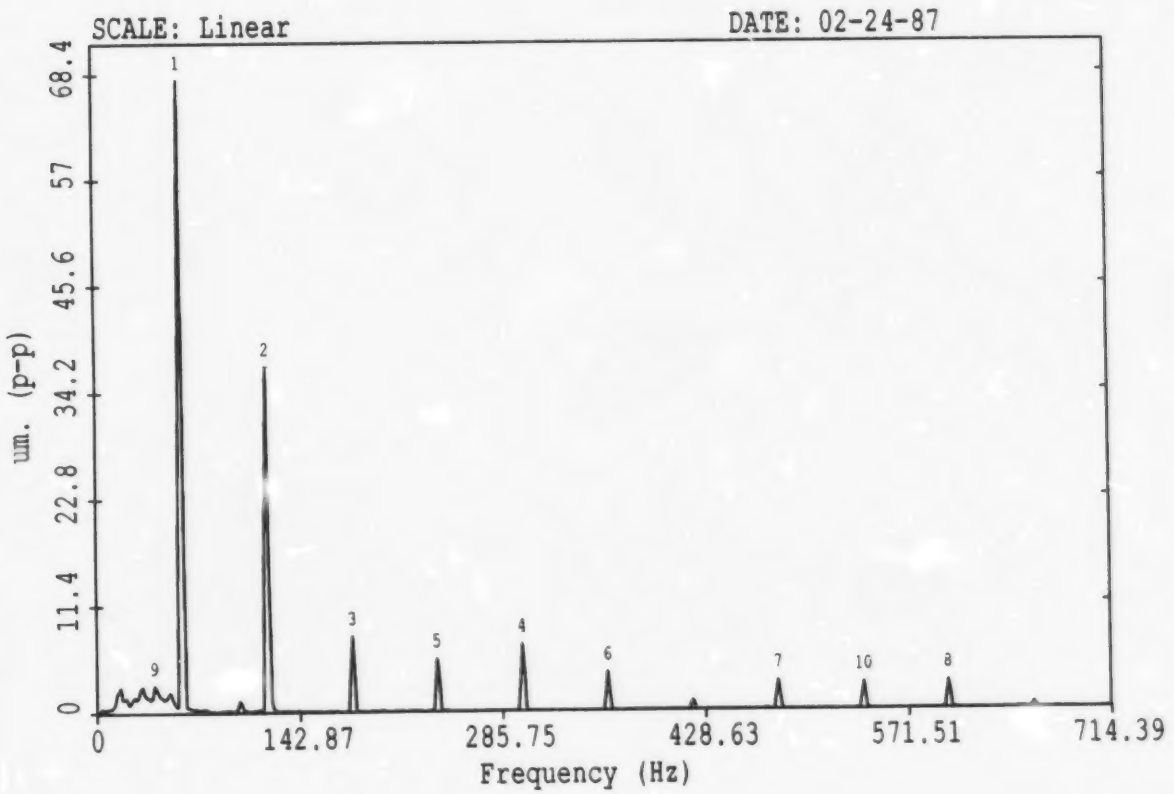


FIGURE 85

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	4.68
2	120.0	2.00	4.27
3	20.9	0.35	3.21
4	180.0	3.00	2.96
5	240.0	4.00	1.66
6	32.1	0.53	1.26
7	480.0	8.00	1.22
8	15.3	0.26	1.21
9	100.5	1.67	0.79
10	420.0	7.00	0.78

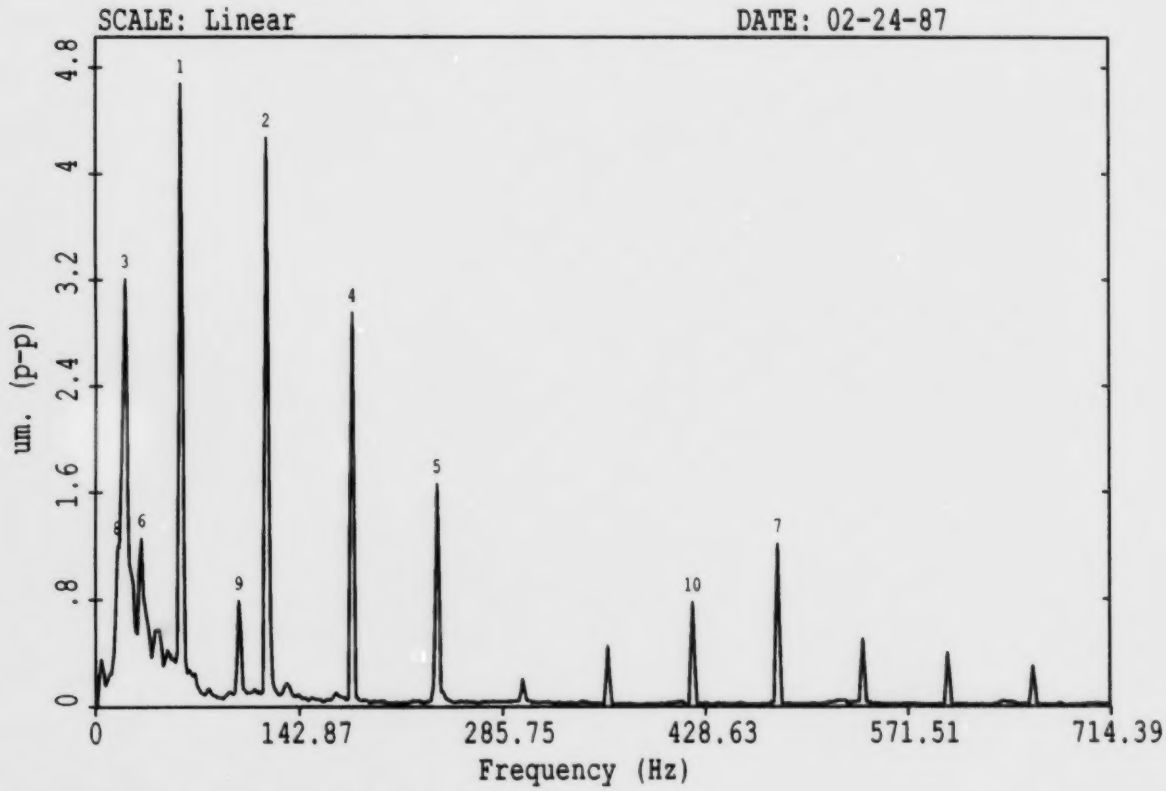


FIGURE 86

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	10.56
2	20.9	0.35	9.72
3	120.0	2.00	6.70
4	32.1	0.53	3.81
5	43.3	0.72	1.65
6	240.0	4.00	1.65
7	100.5	1.67	1.56
8	40.5	0.67	1.40
9	480.0	8.00	1.22
10	50.2	0.84	1.15

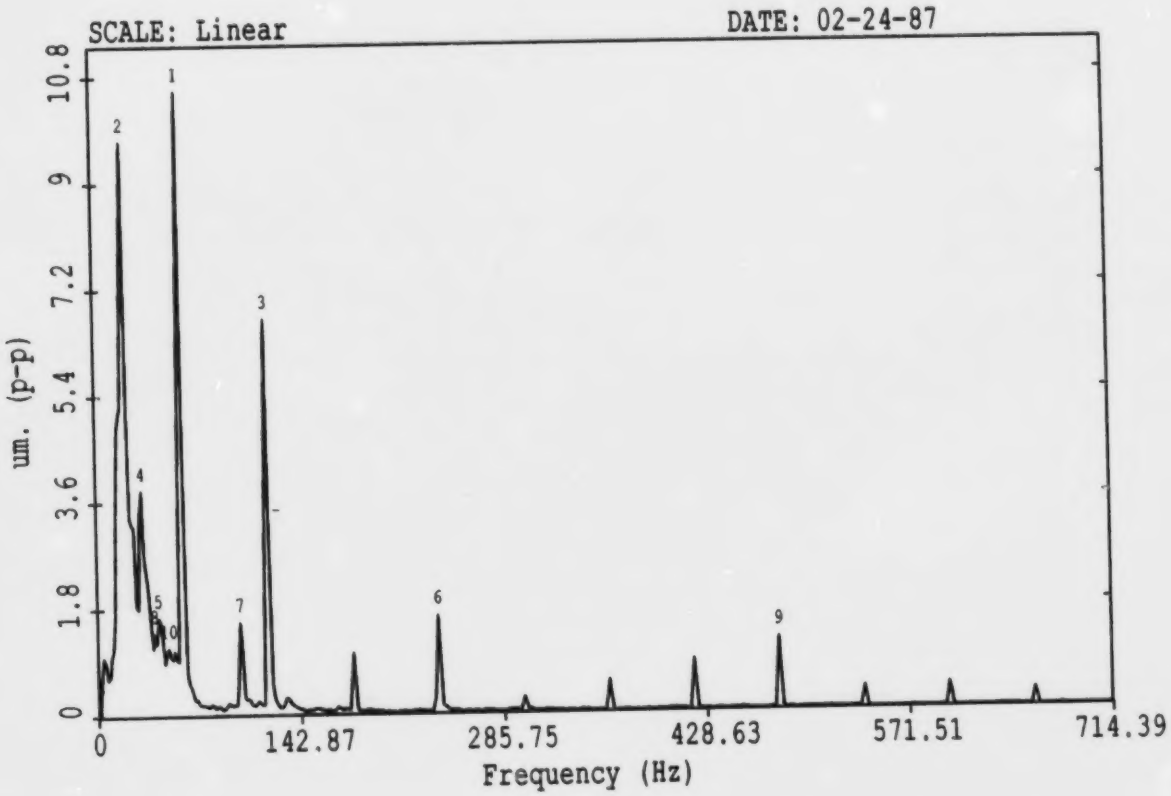


FIGURE 87

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	89.82
2	120.0	2.00	35.34
3	180.0	3.00	13.58
4	300.0	5.00	7.32
5	240.0	4.00	5.42
6	32.1	0.53	4.62
7	40.5	0.67	4.25
8	360.0	6.00	4.23
9	29.3	0.49	4.18
10	16.7	0.28	4.13

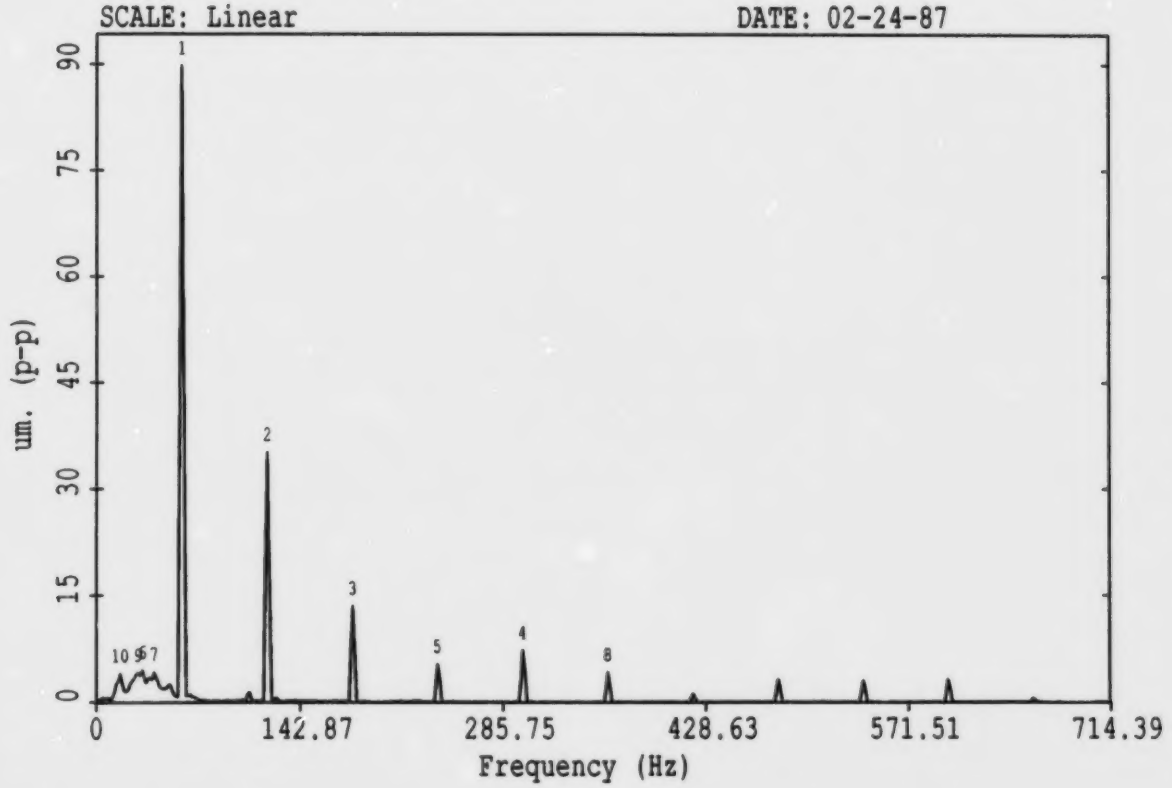


FIGURE 88

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	70.89
2	120.0	2.00	36.95
3	180.0	3.00	7.99
4	300.0	5.00	7.31
5	240.0	4.00	5.67
6	360.0	6.00	4.16
7	480.0	8.00	3.24
8	600.0	10.00	3.15
9	540.0	9.00	3.07
10	40.5	0.67	2.19

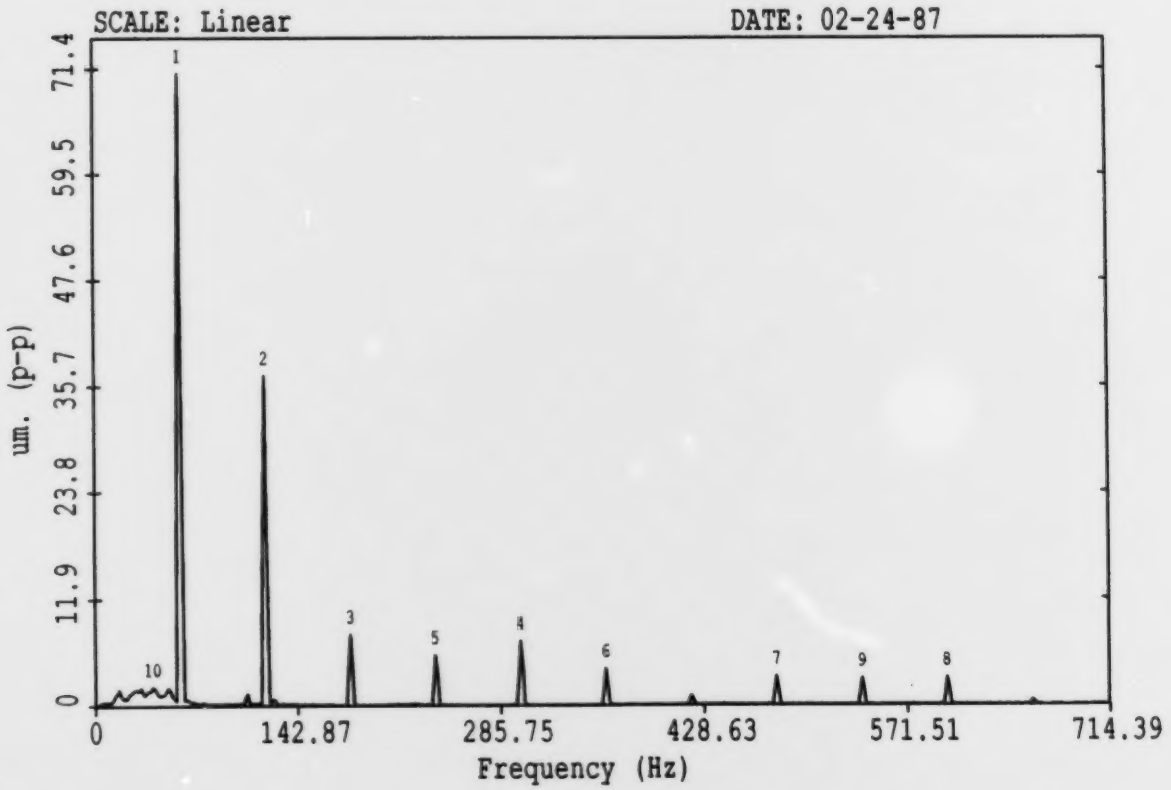


FIGURE 89

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	4.79
2	120.0	2.00	4.47
3	180.0	3.00	3.21
4	19.5	0.33	2.01
5	240.0	4.00	1.75
6	480.0	8.00	1.26
7	26.5	0.44	0.98
8	32.1	0.53	0.83
9	420.0	7.00	0.82
10	540.0	9.00	0.55

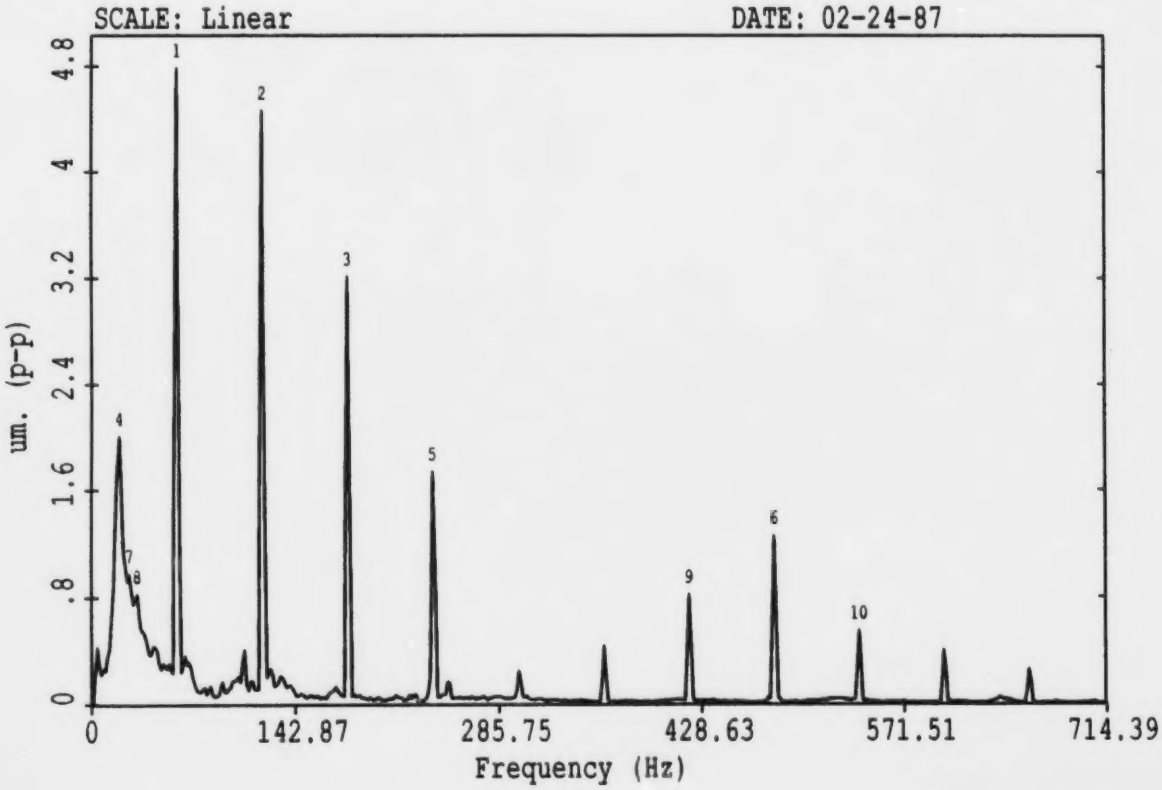


FIGURE 90

88-241

Darlington GS Standby Generator #1 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.61
2	120.0	2.00	6.55
3	19.5	0.33	5.89
4	26.5	0.44	3.09
5	32.1	0.53	2.50
6	37.7	0.63	1.66
7	240.0	4.00	1.61
8	40.5	0.67	1.47
9	480.0	8.00	1.18
10	180.0	3.00	1.12

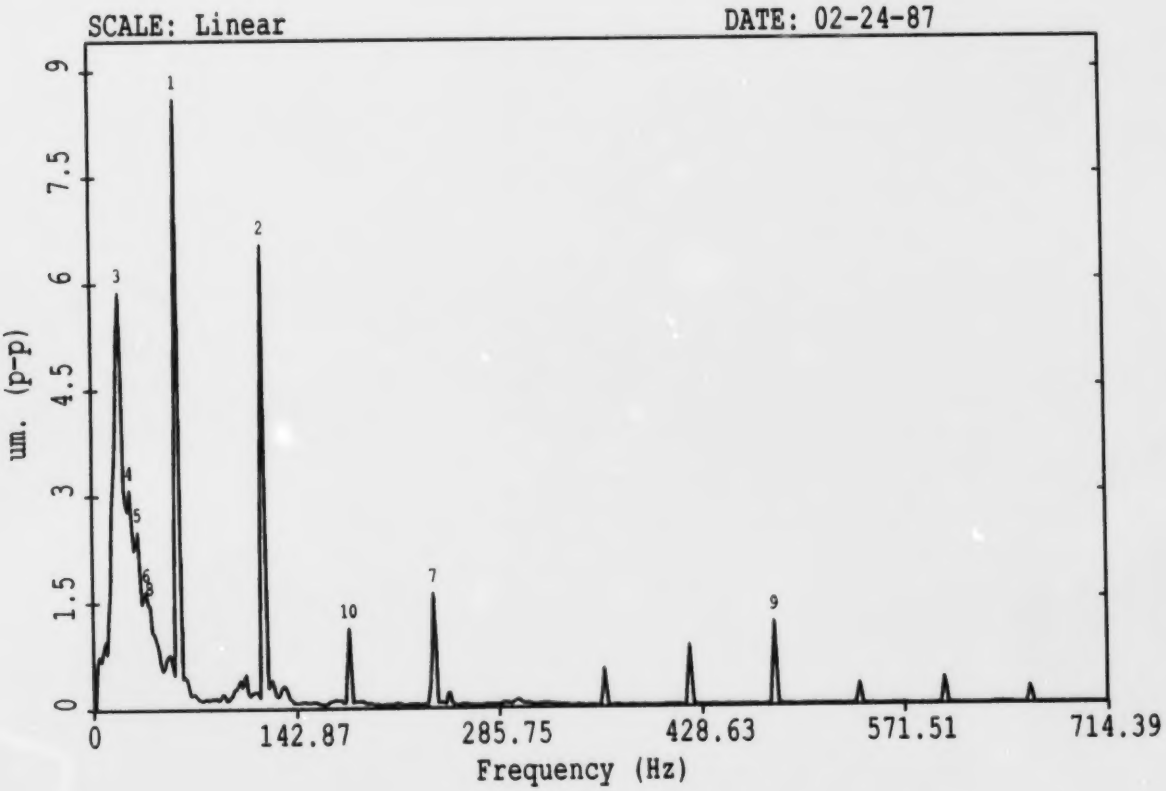


FIGURE 91

88-241

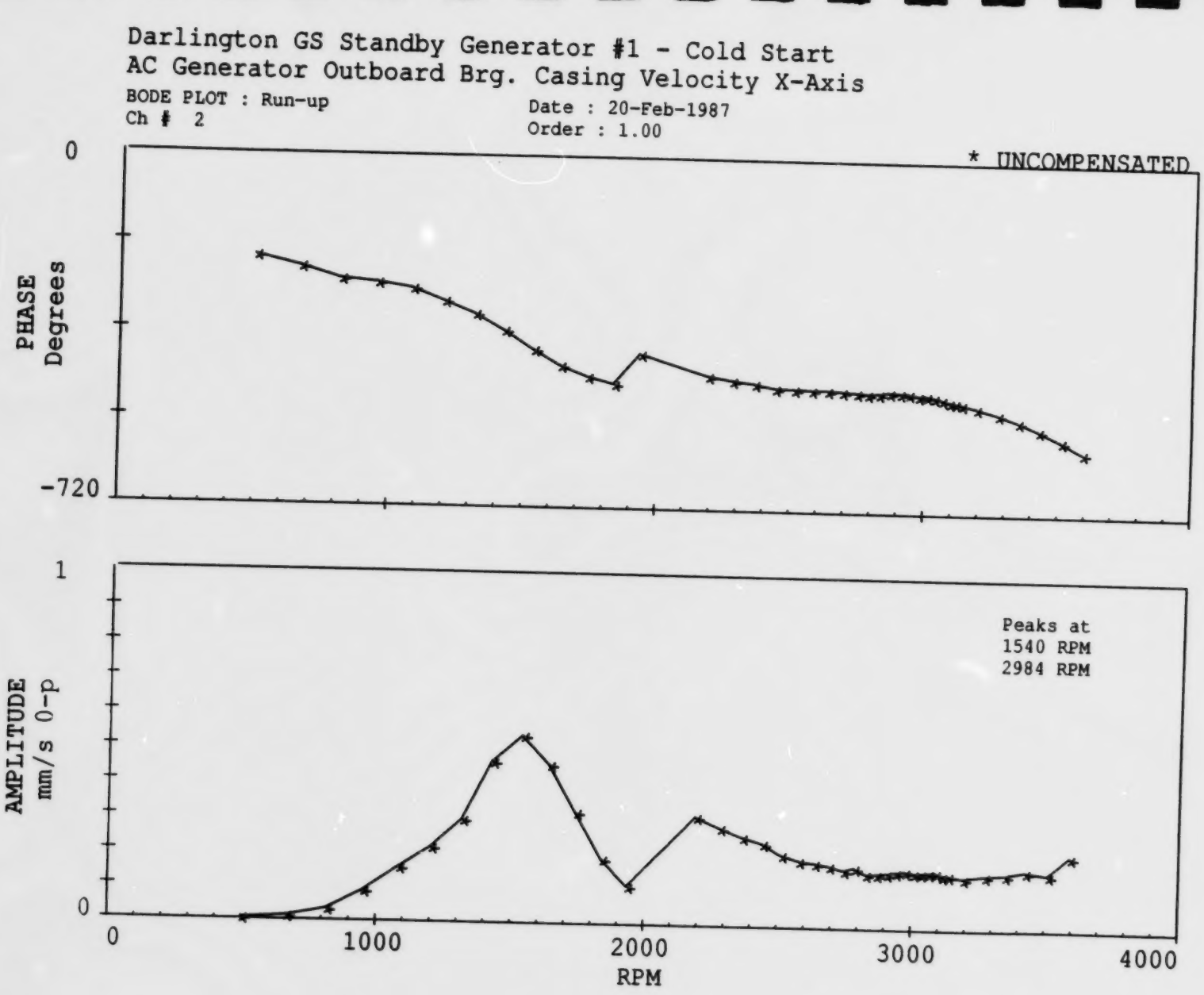


FIGURE 92
88-241

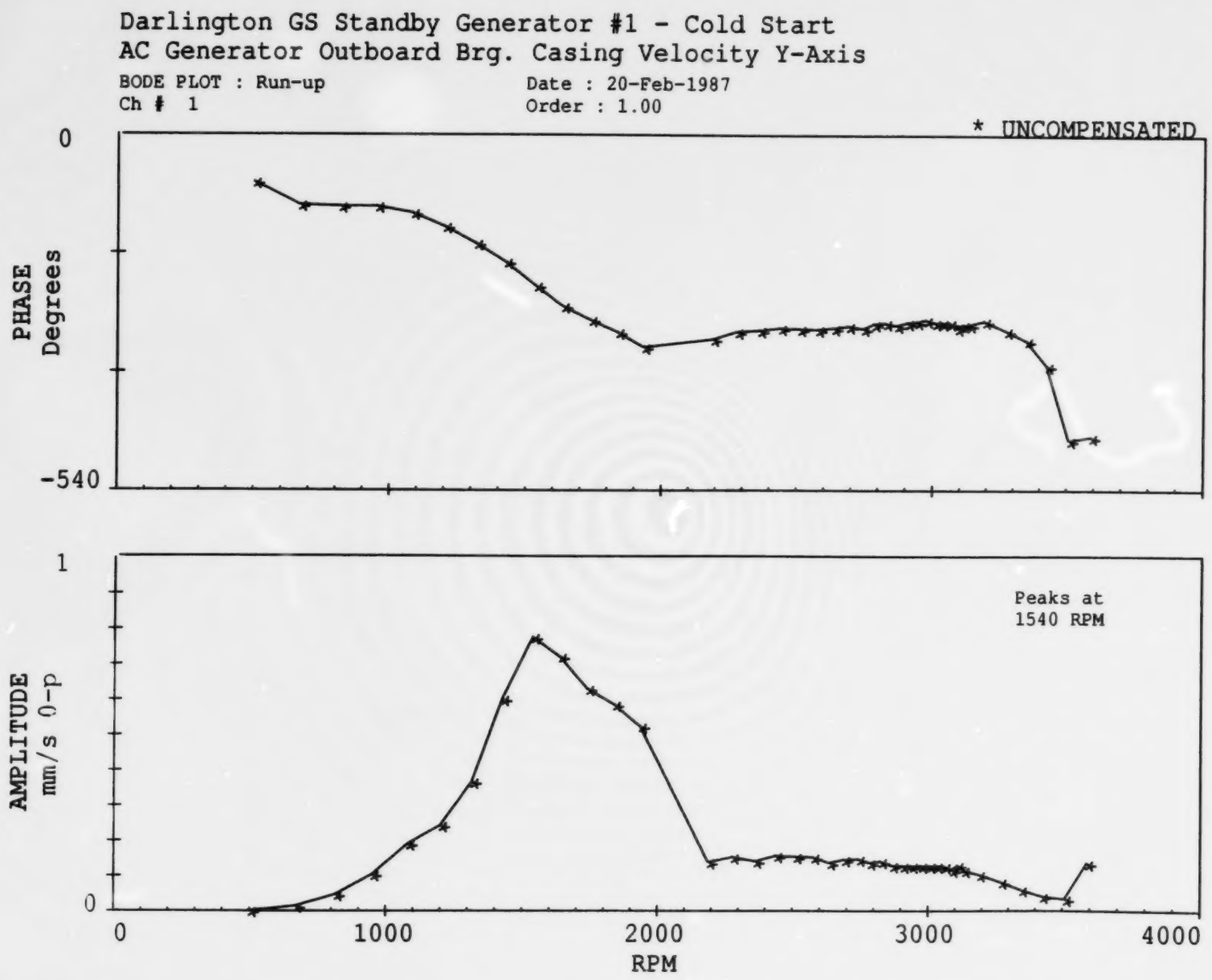


FIGURE 93

88-241

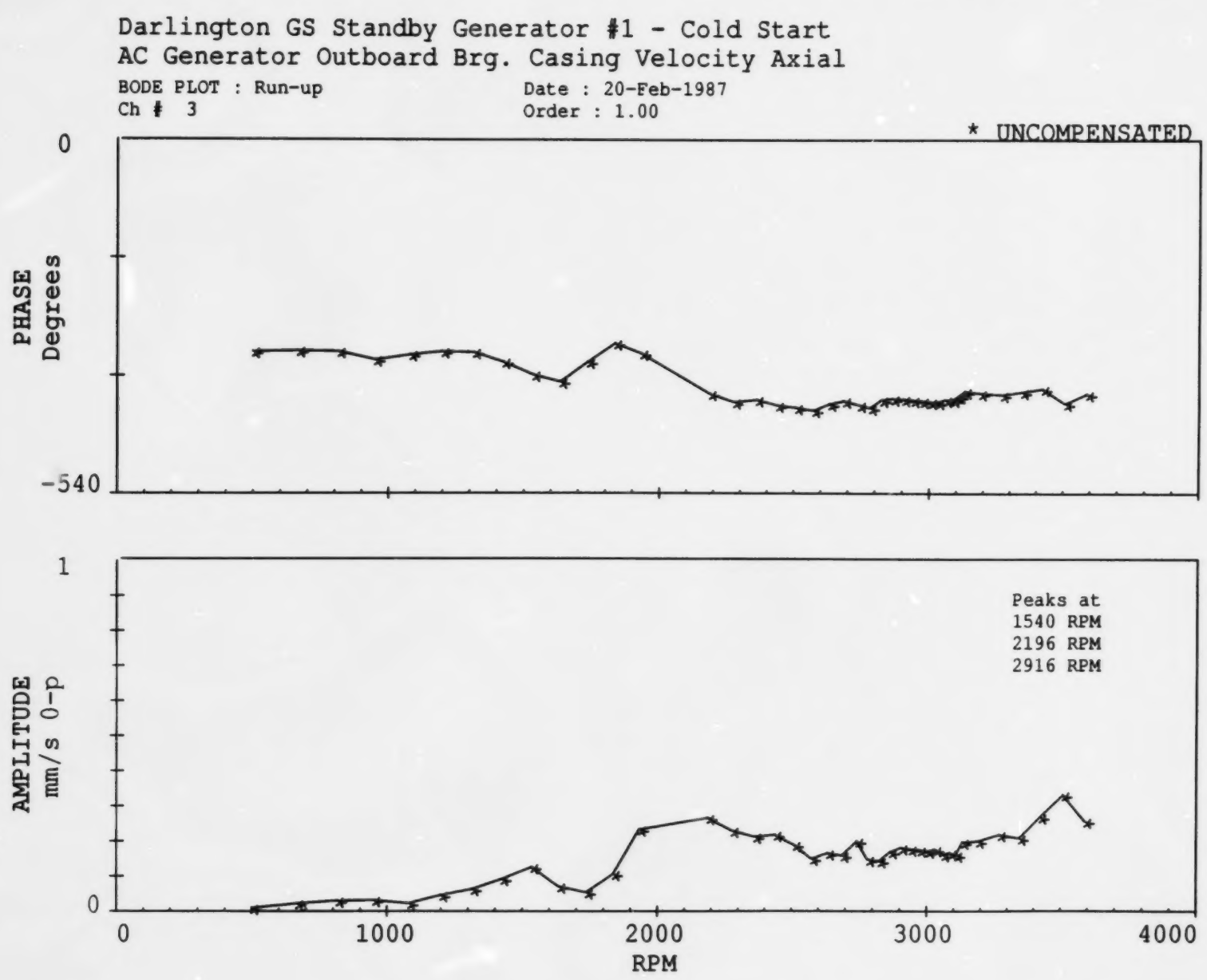


FIGURE 94
88-241

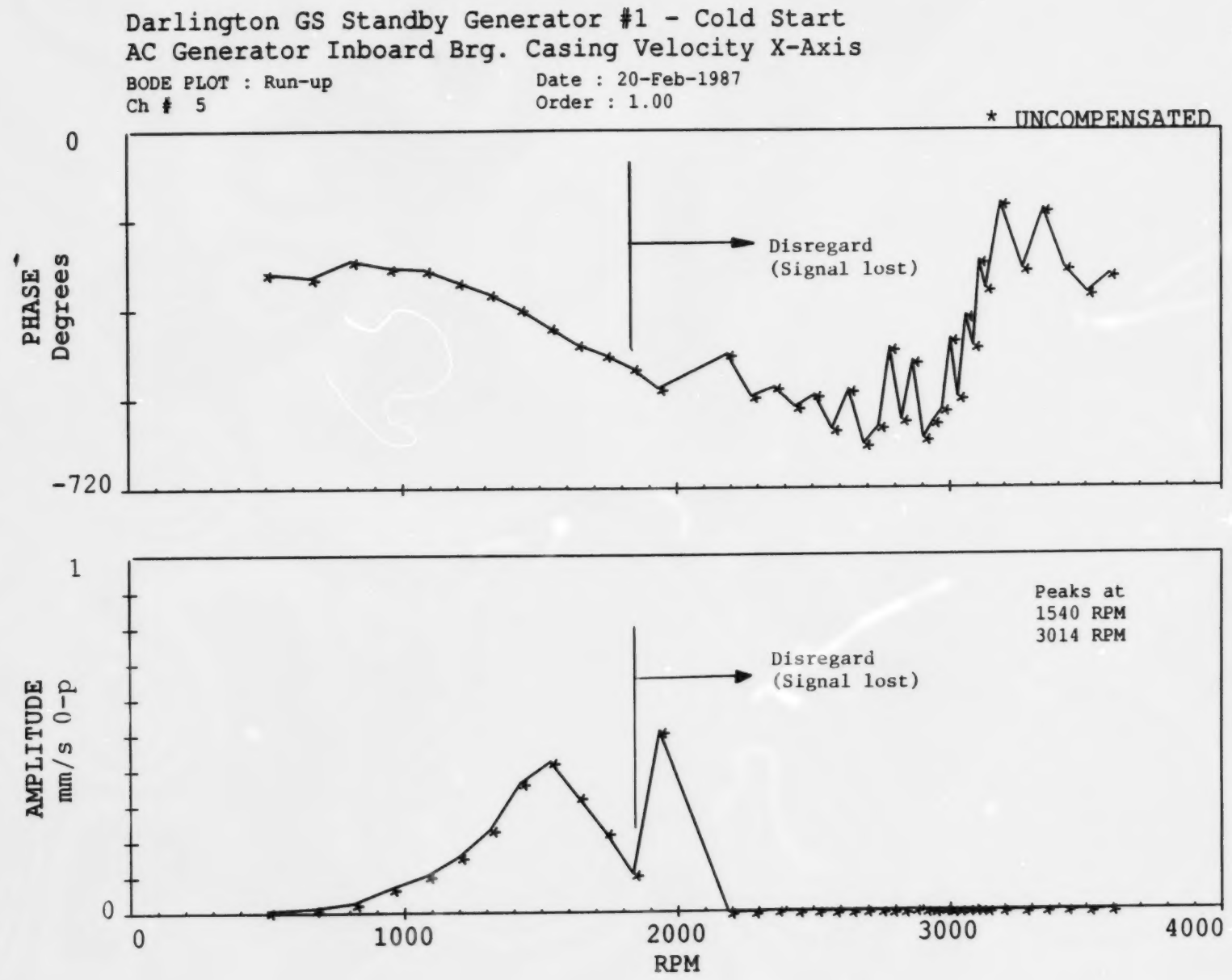


FIGURE 95

88-241

Darlington GS Standby Generator #1 - Cold Start
AC Generator Inboard Brg. Casing Velocity Y-Axis

BODE PLOT : Run-up
Ch # 4

Date : 20-Feb-1987
Order : 1.00

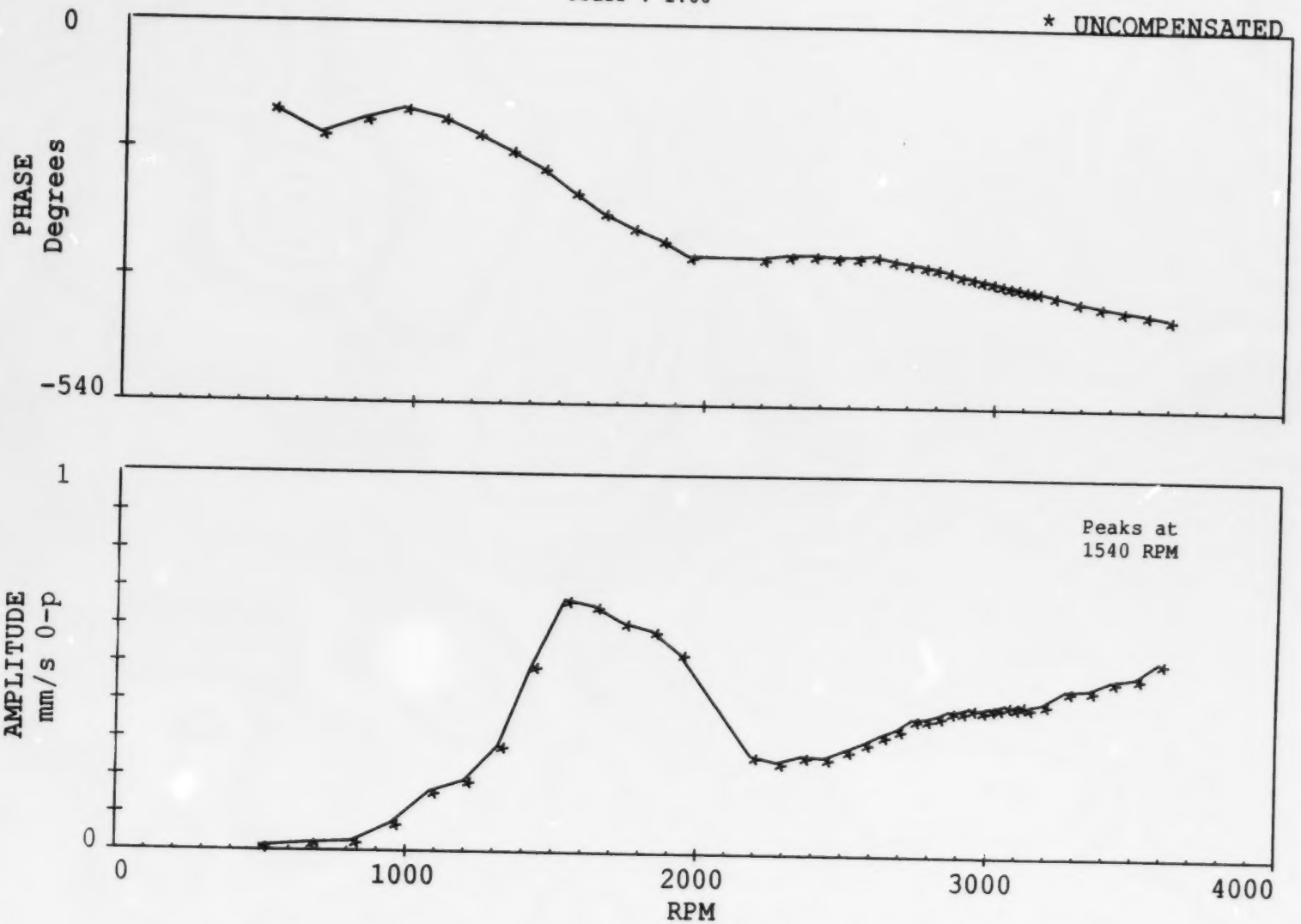


FIGURE 96

88-241

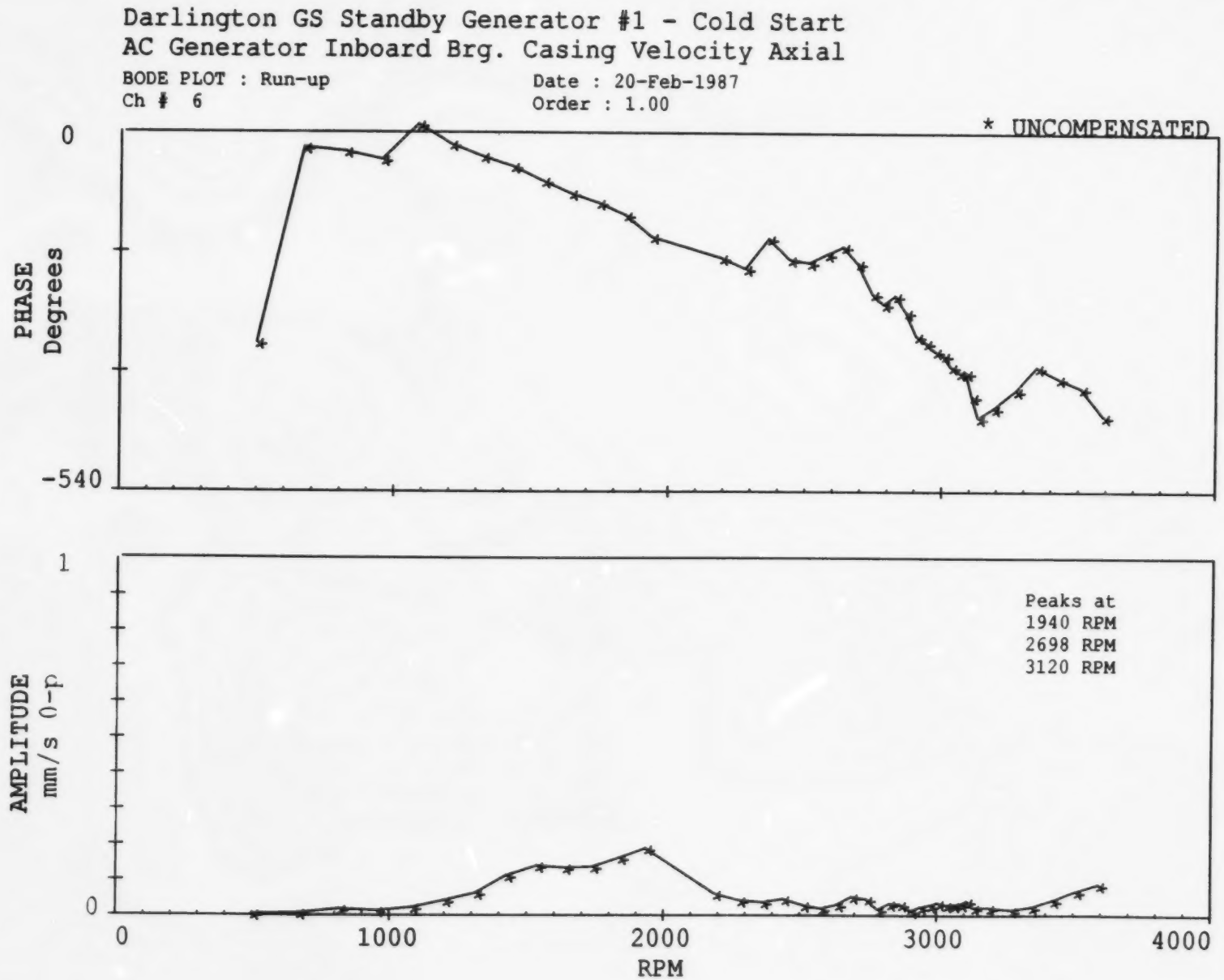


FIGURE 97
88-241

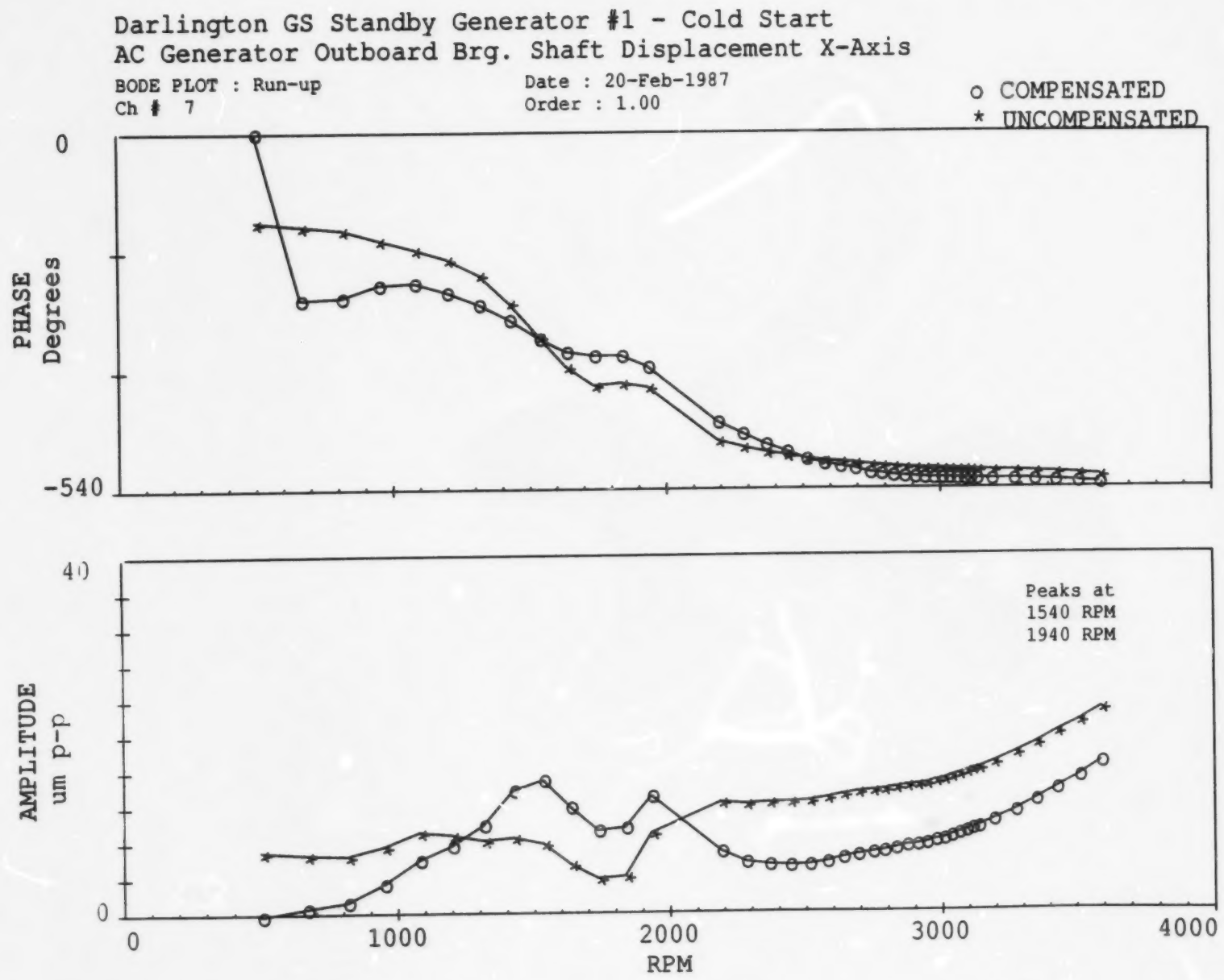


FIGURE 98

88-241

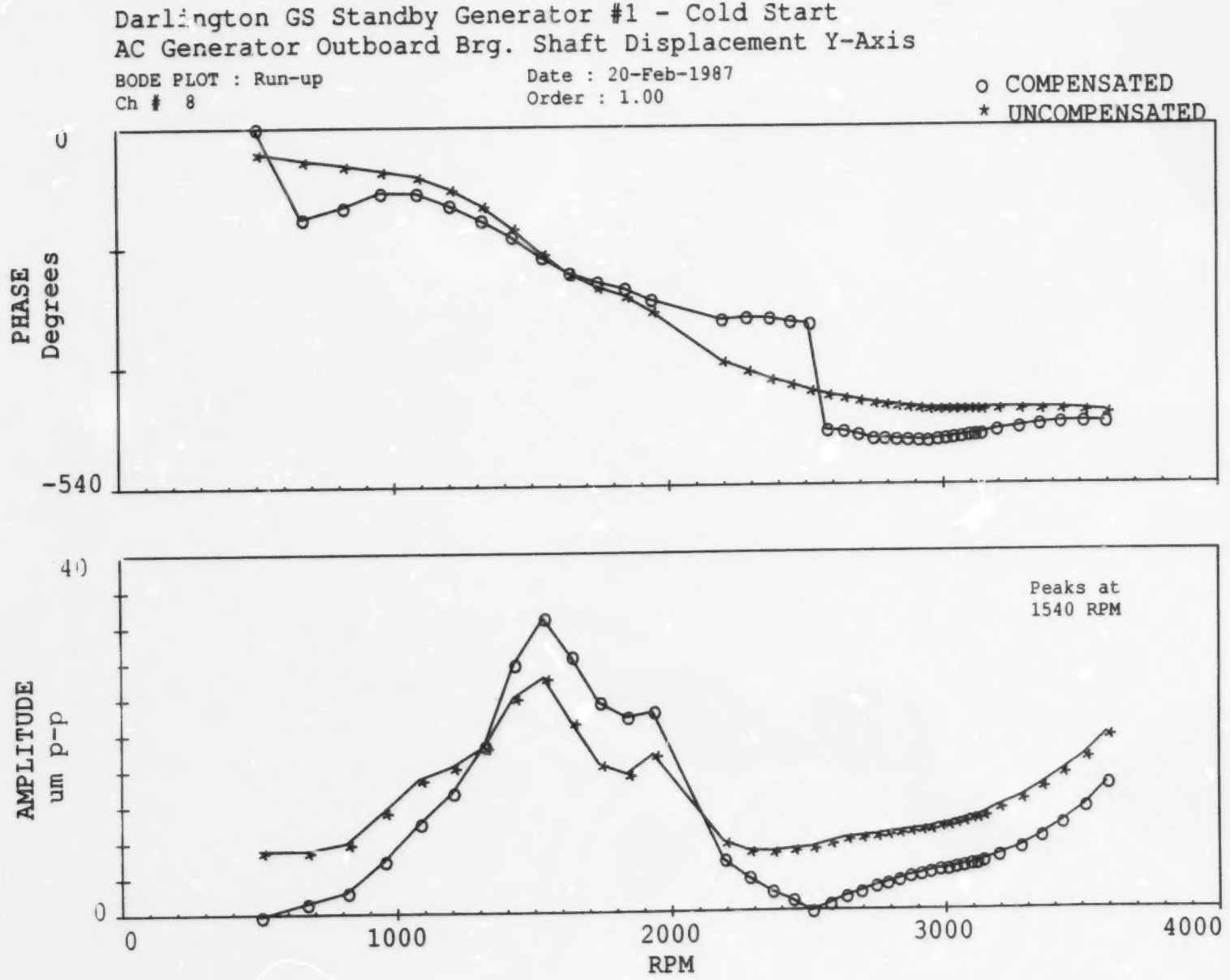


FIGURE 99

88-241

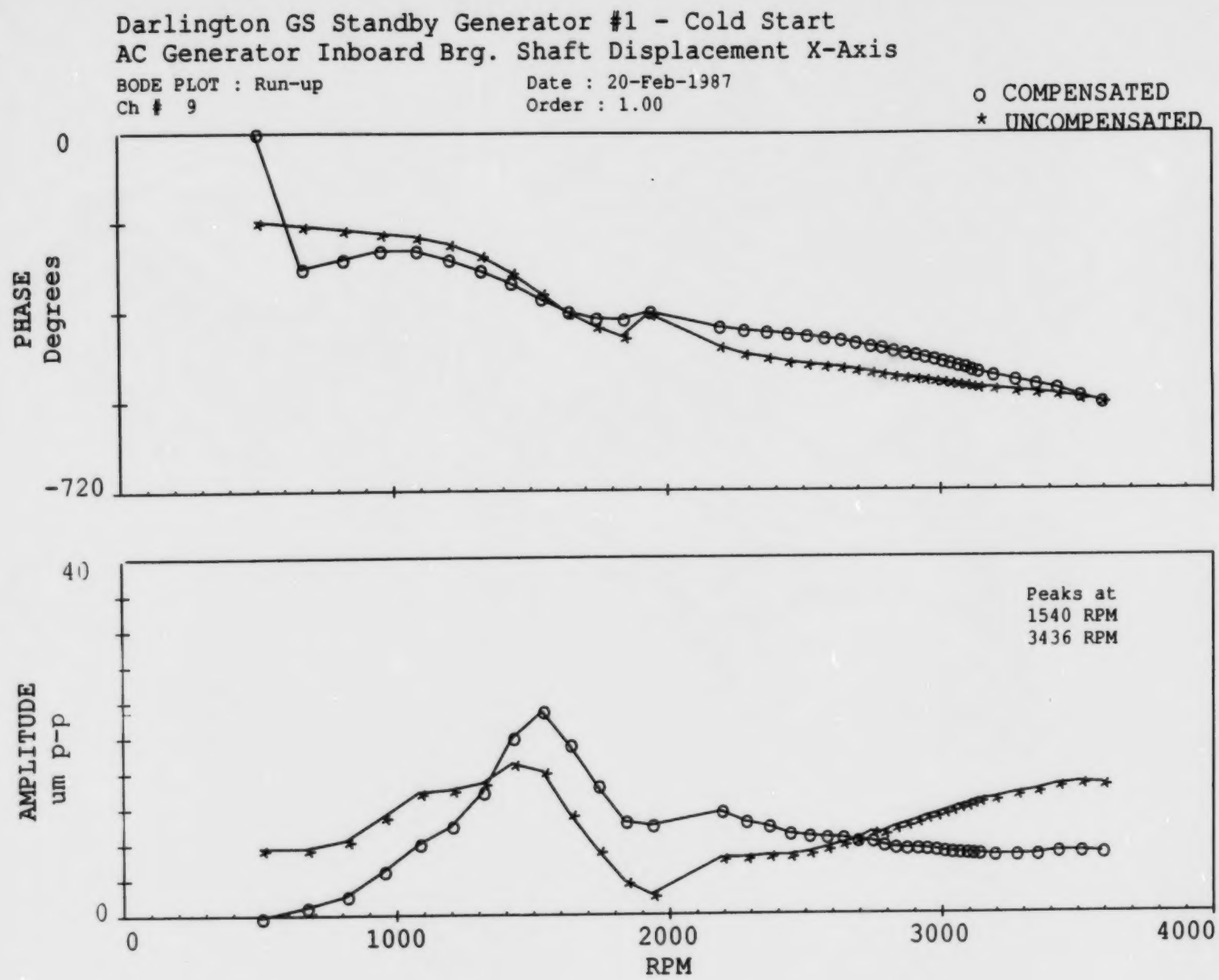


FIGURE 100

88-241

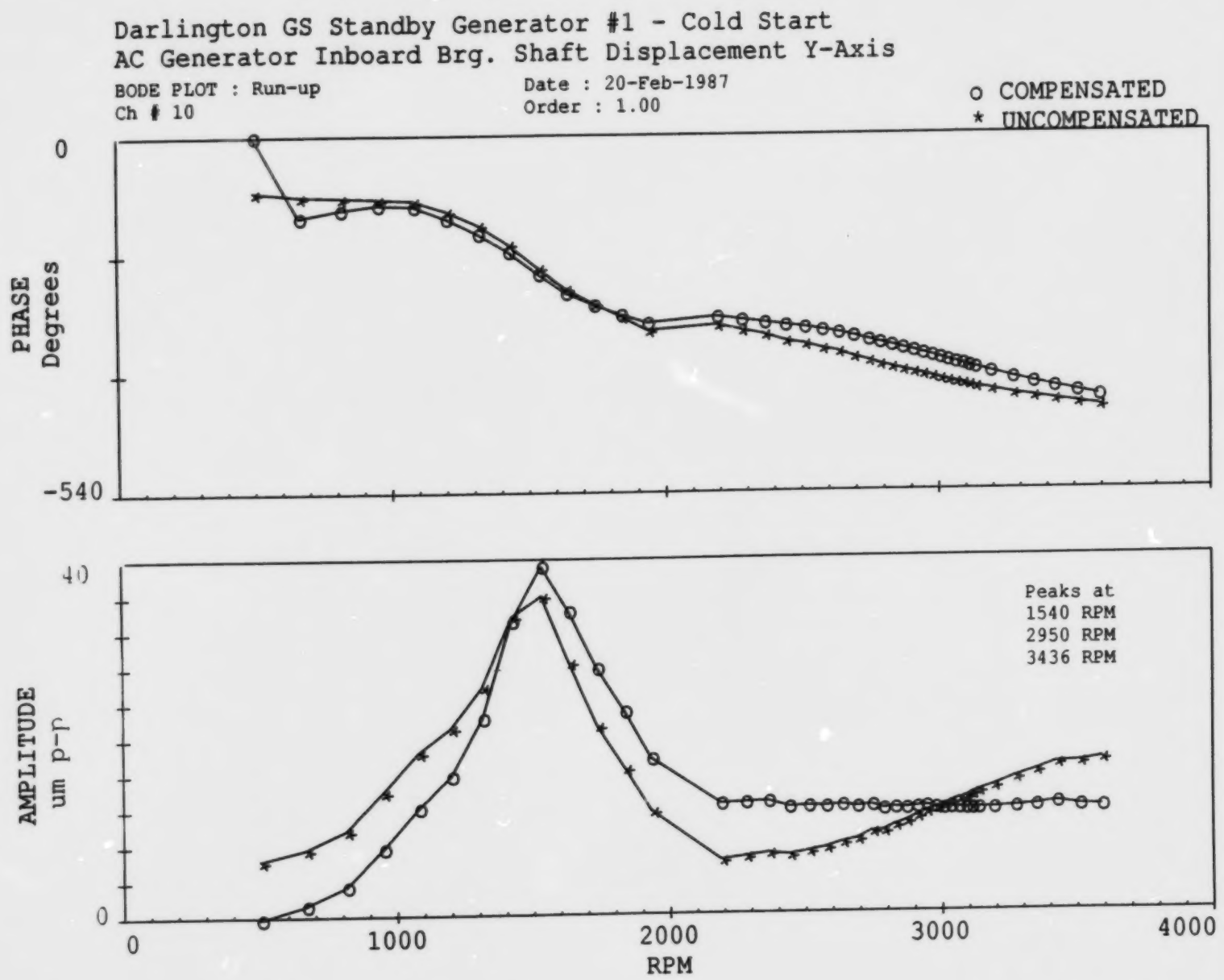


FIGURE 101
88-241

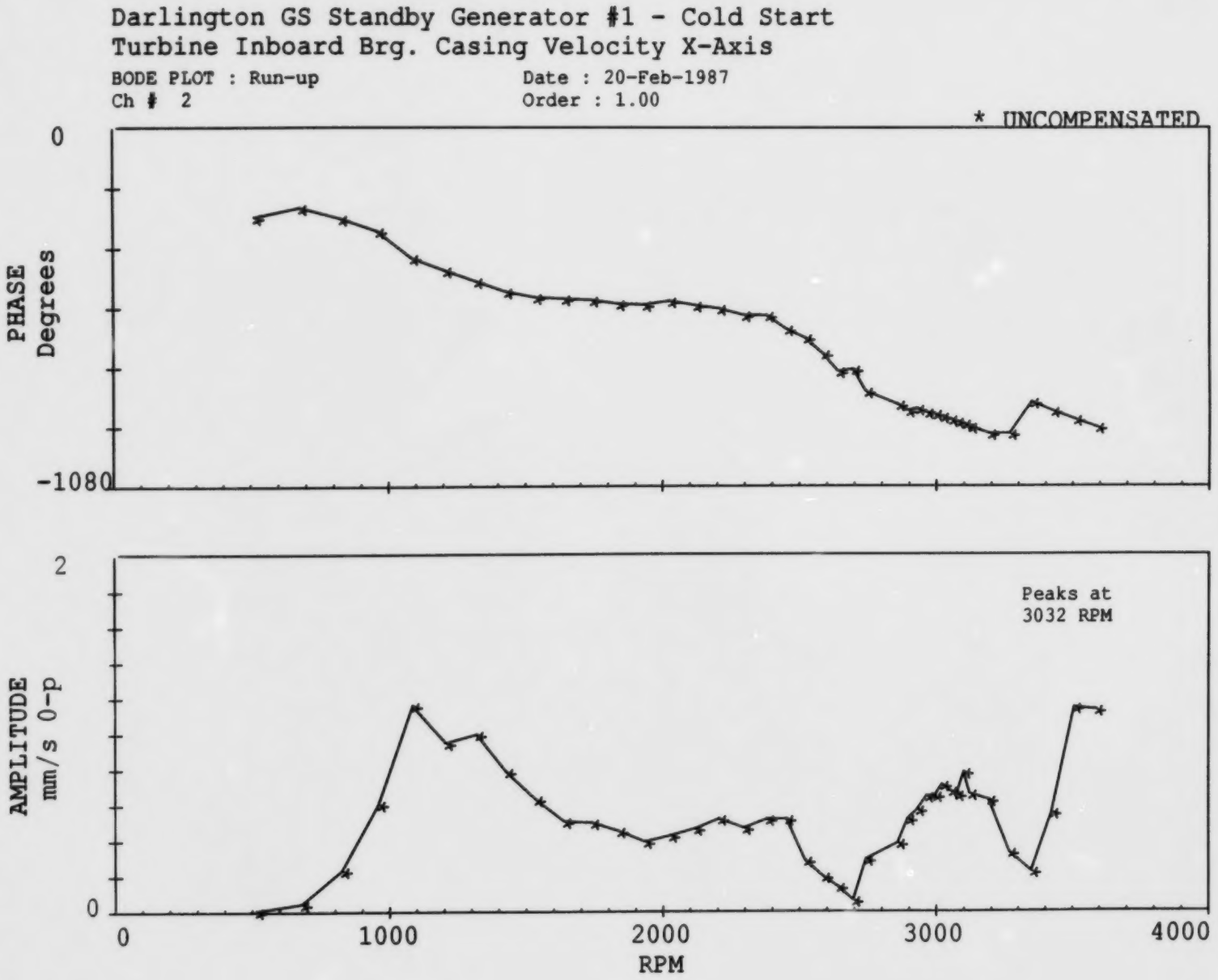


FIGURE 102
88-241

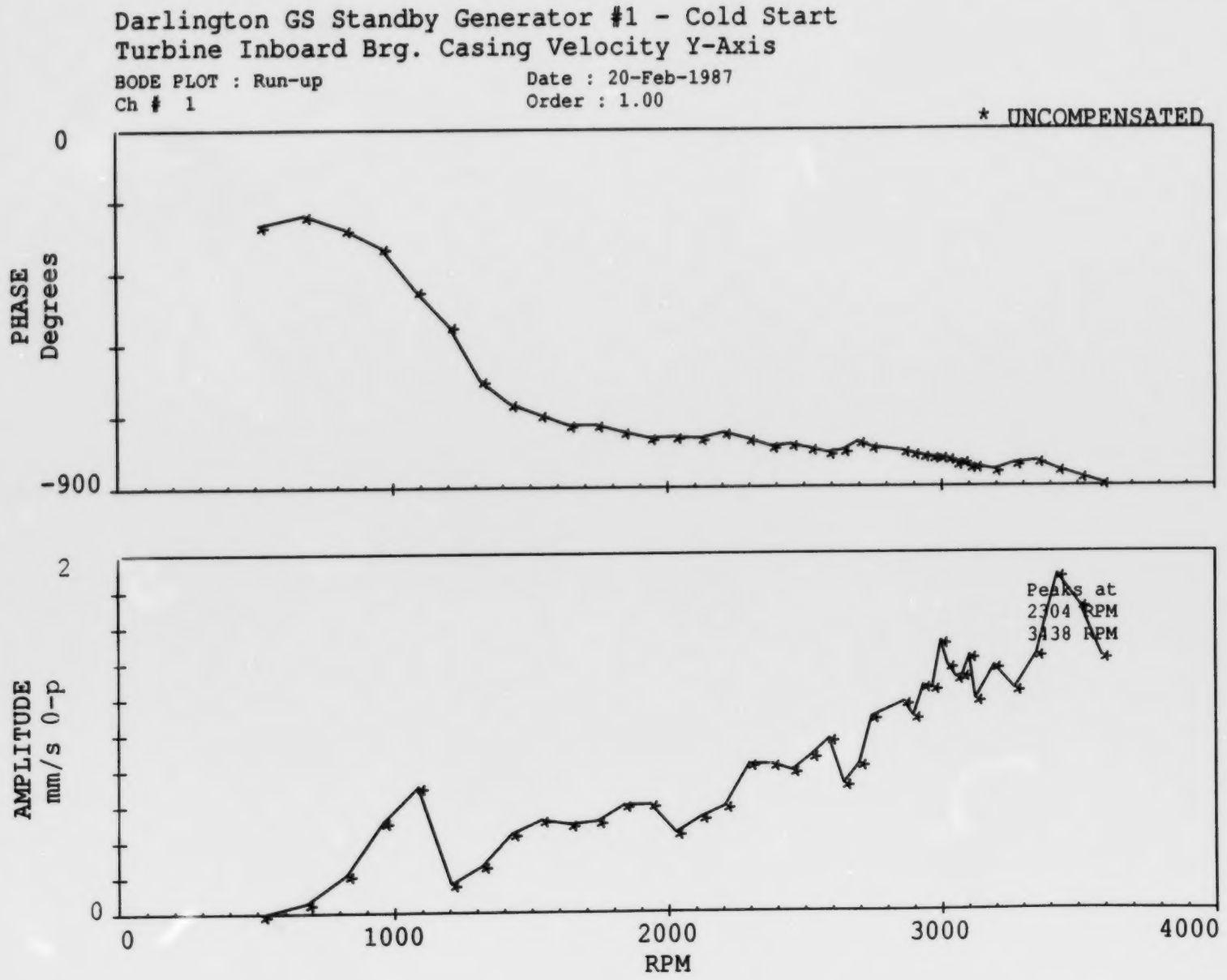


FIGURE 103

88-241

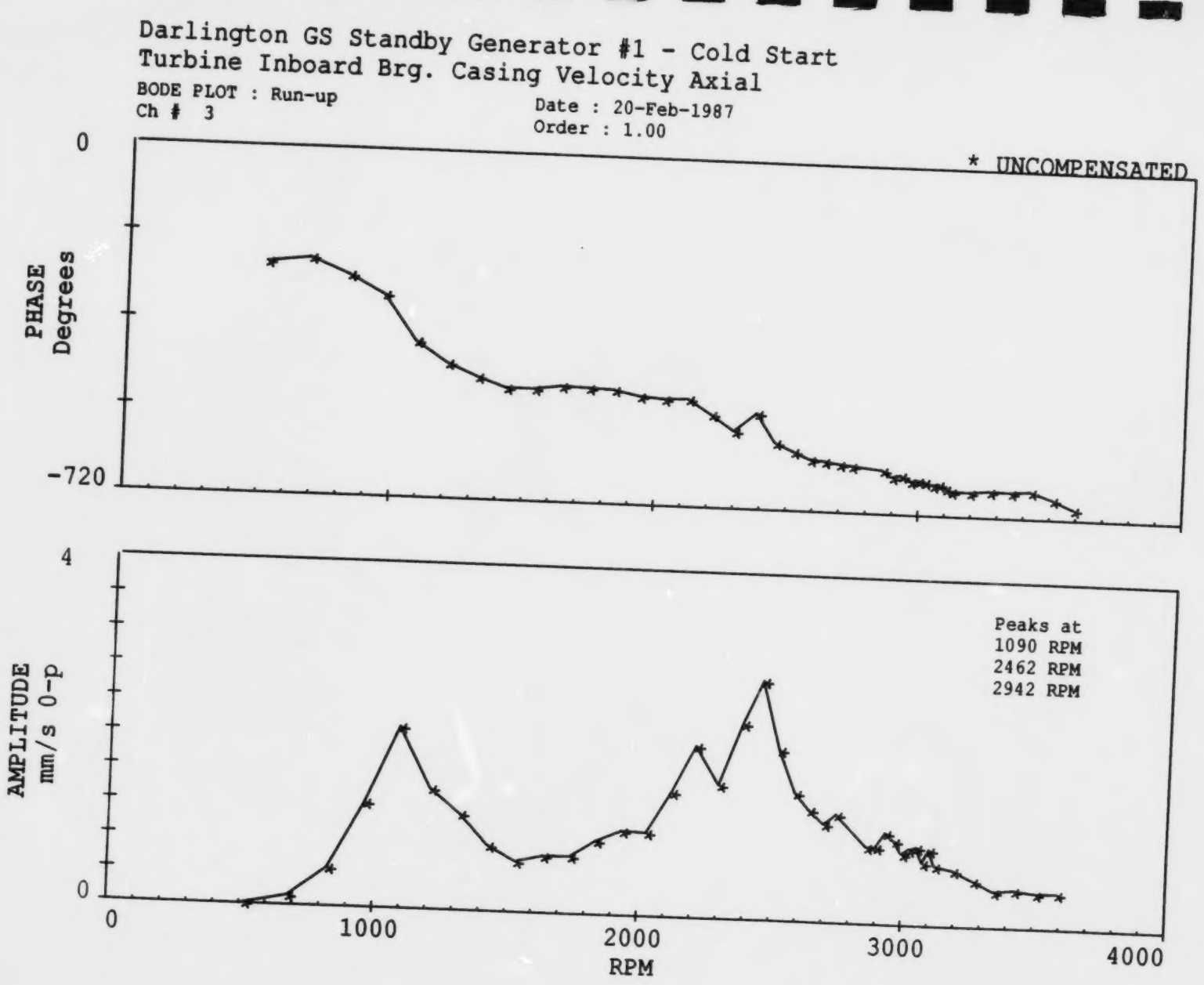


FIGURE 104

88-241

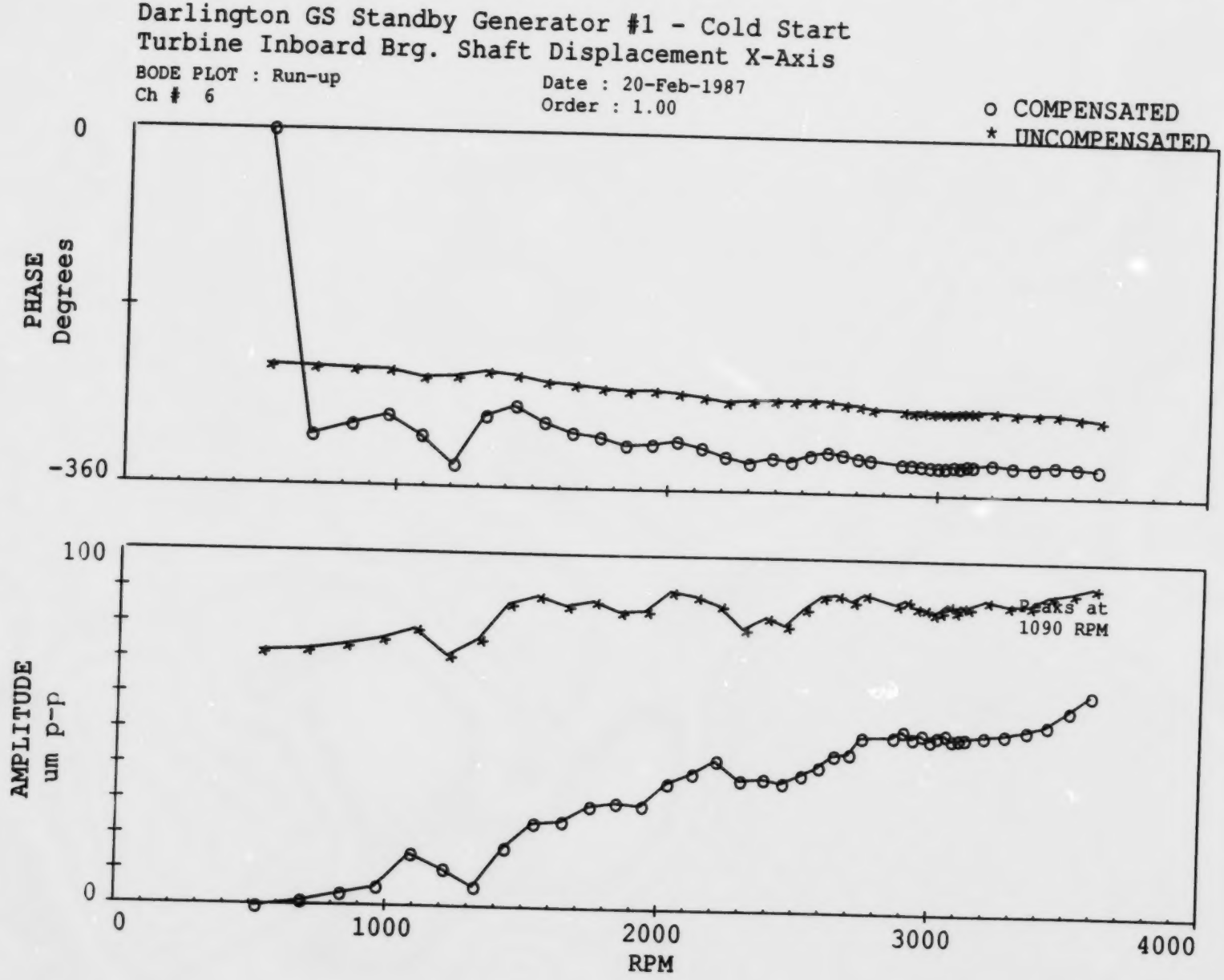


FIGURE 105

88-241

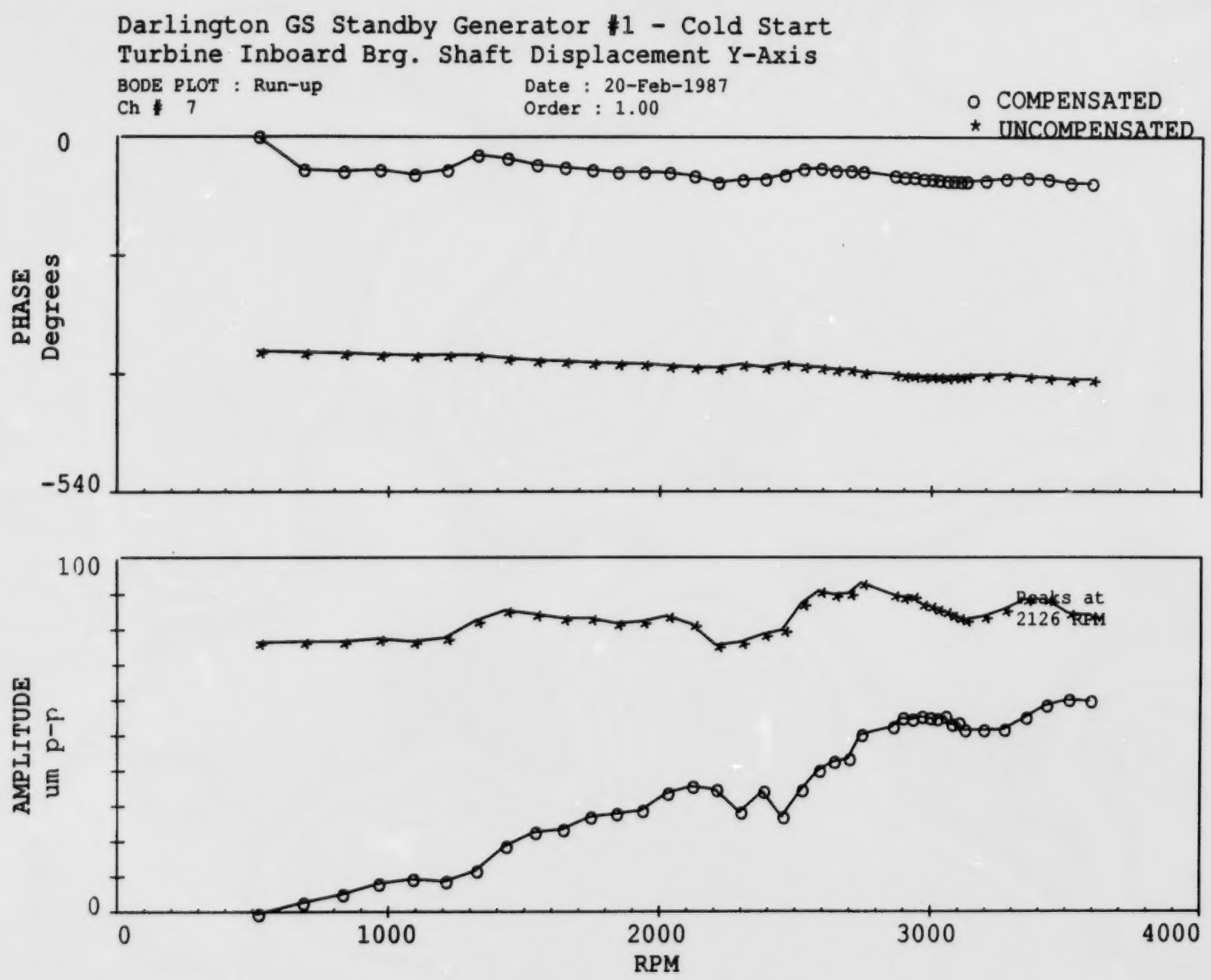


FIGURE 106

88-241

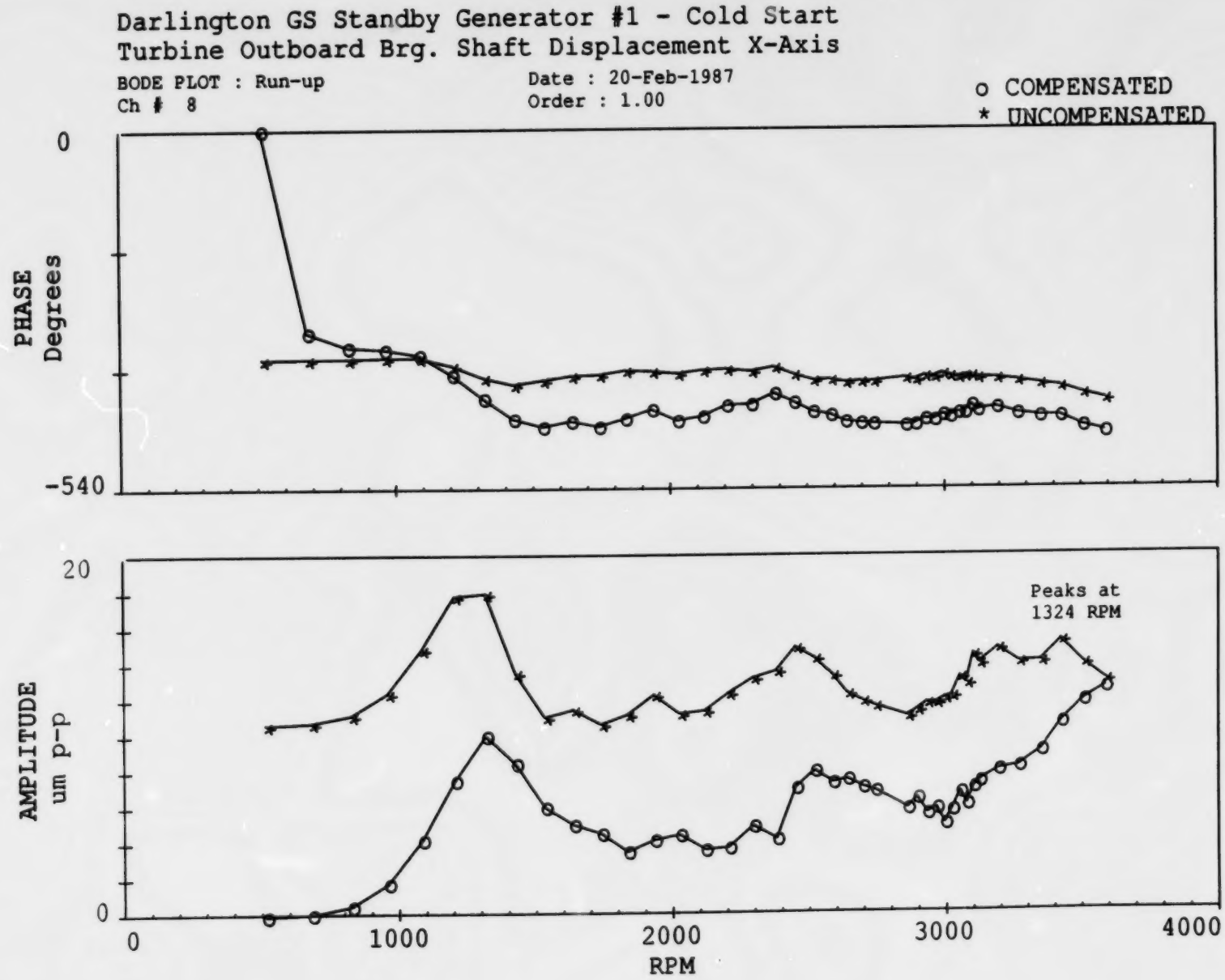


FIGURE 107

88-241

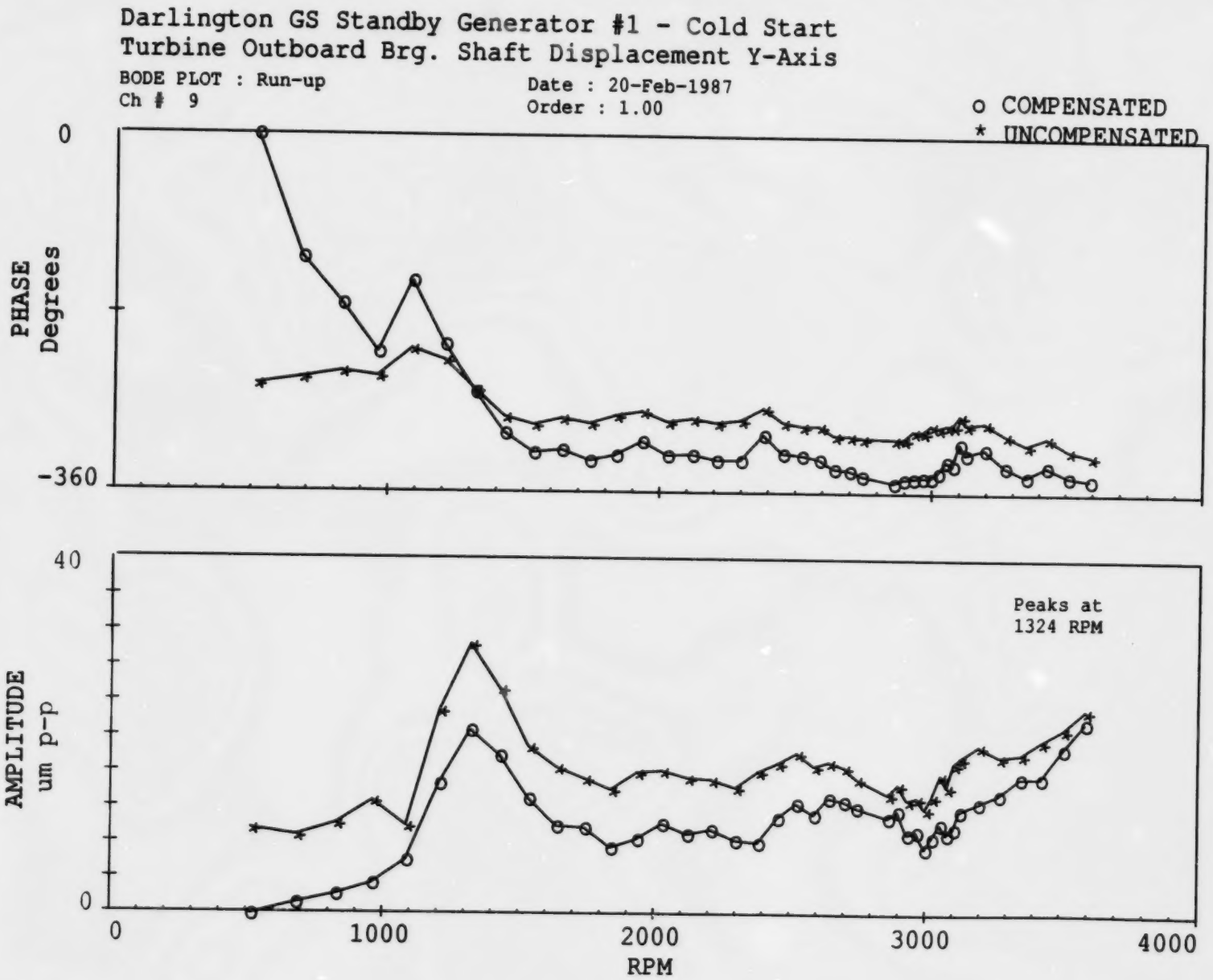


FIGURE 108

88-241

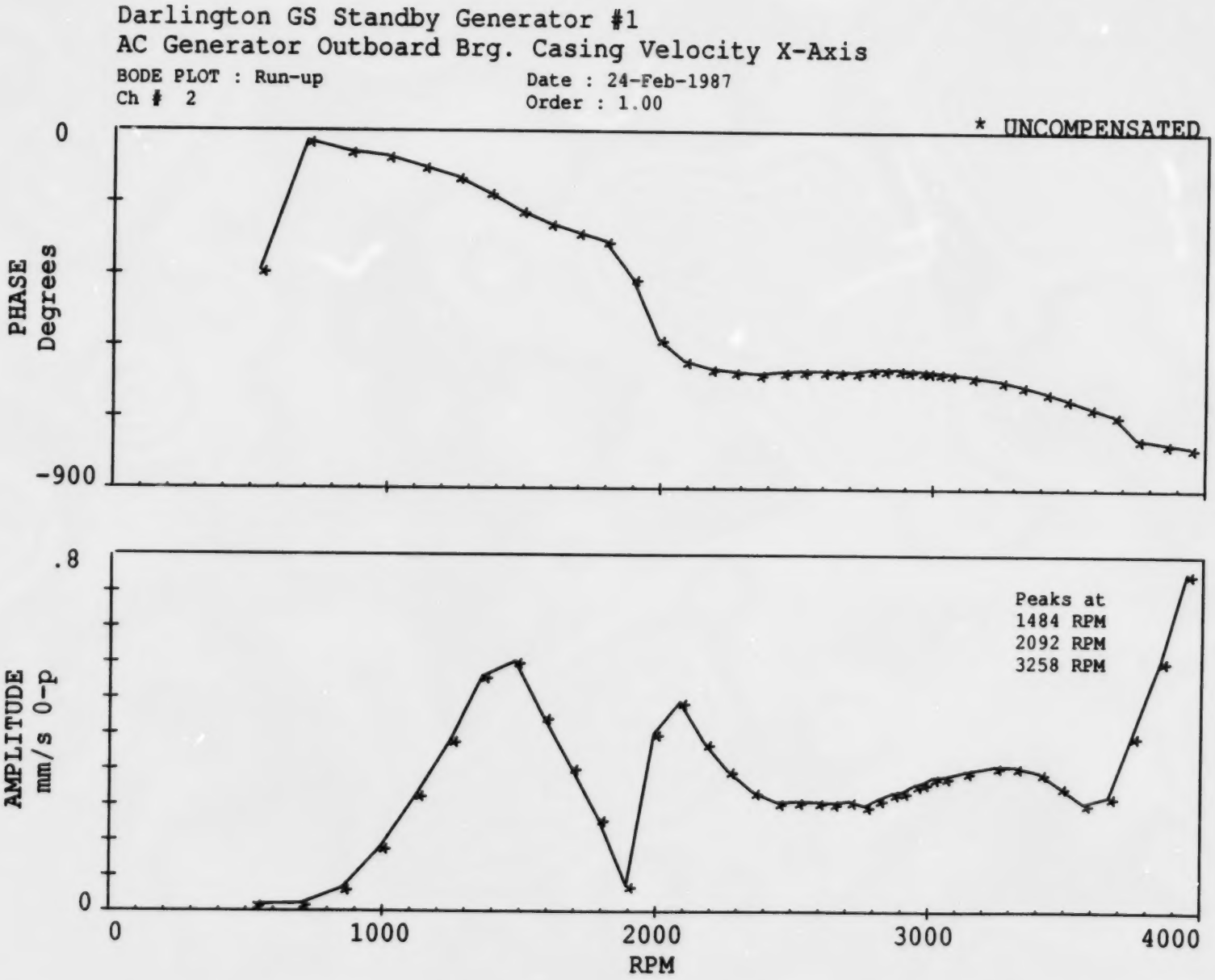


FIGURE 109

88-241

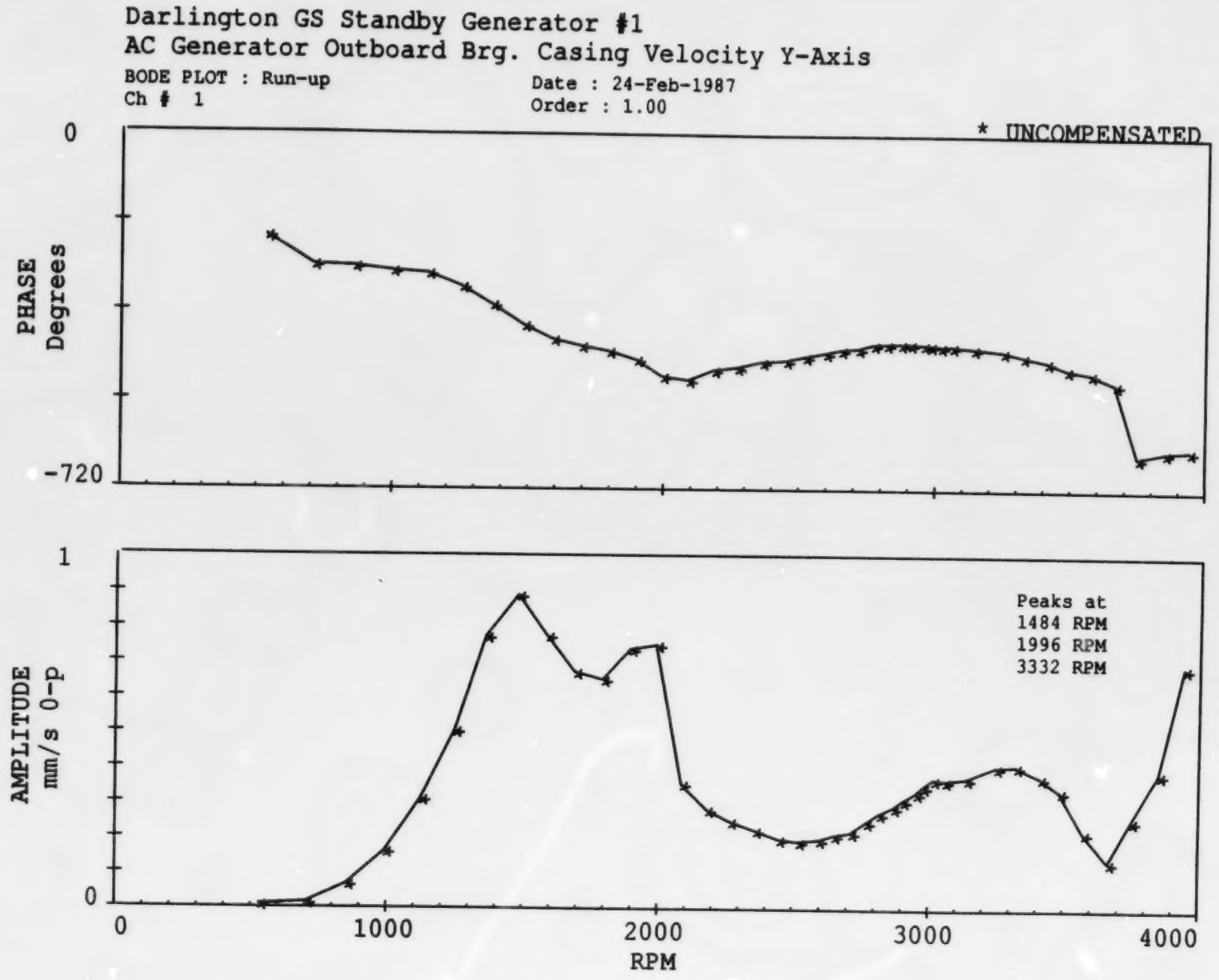


FIGURE 110

88-241

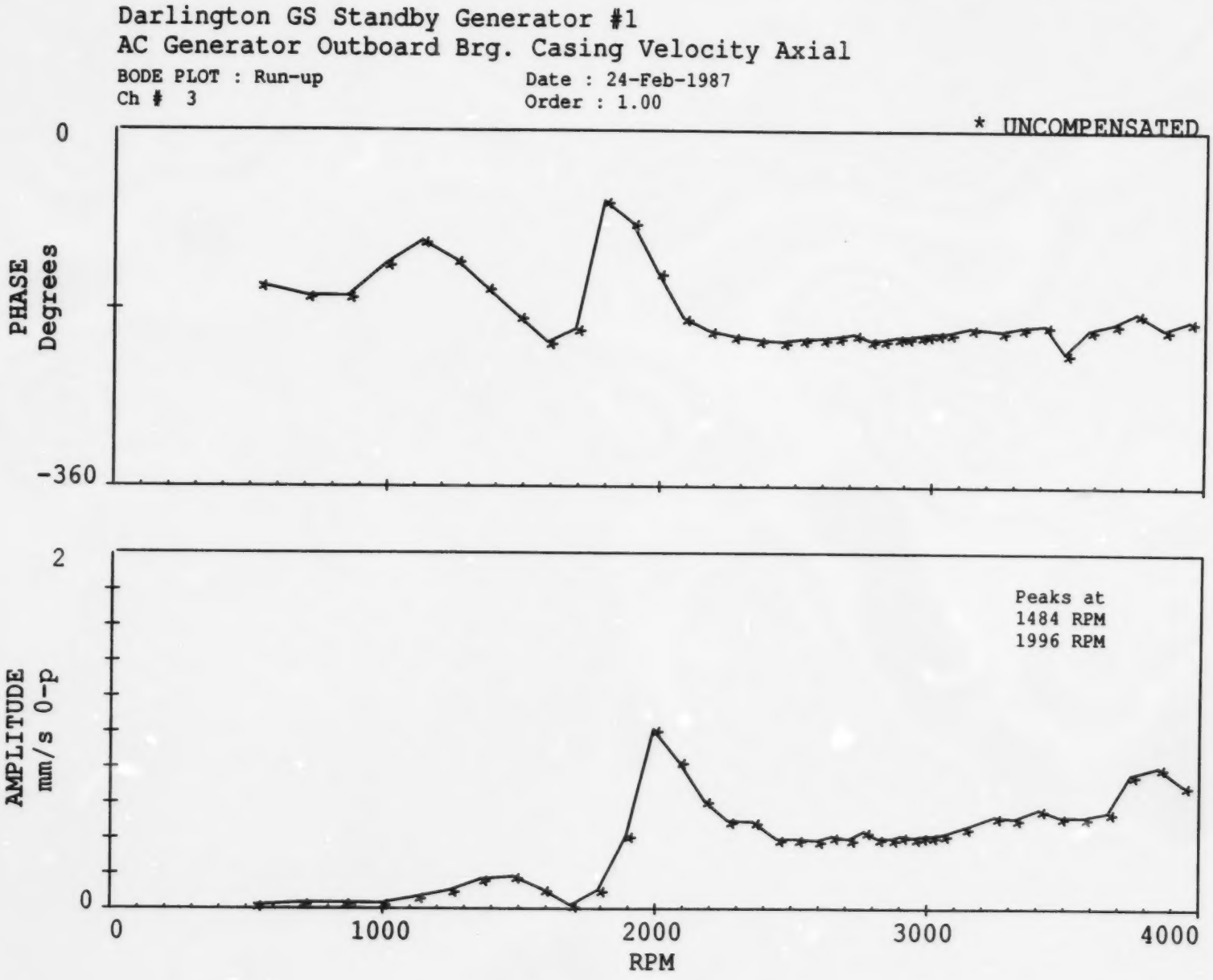


FIGURE 111

88-241

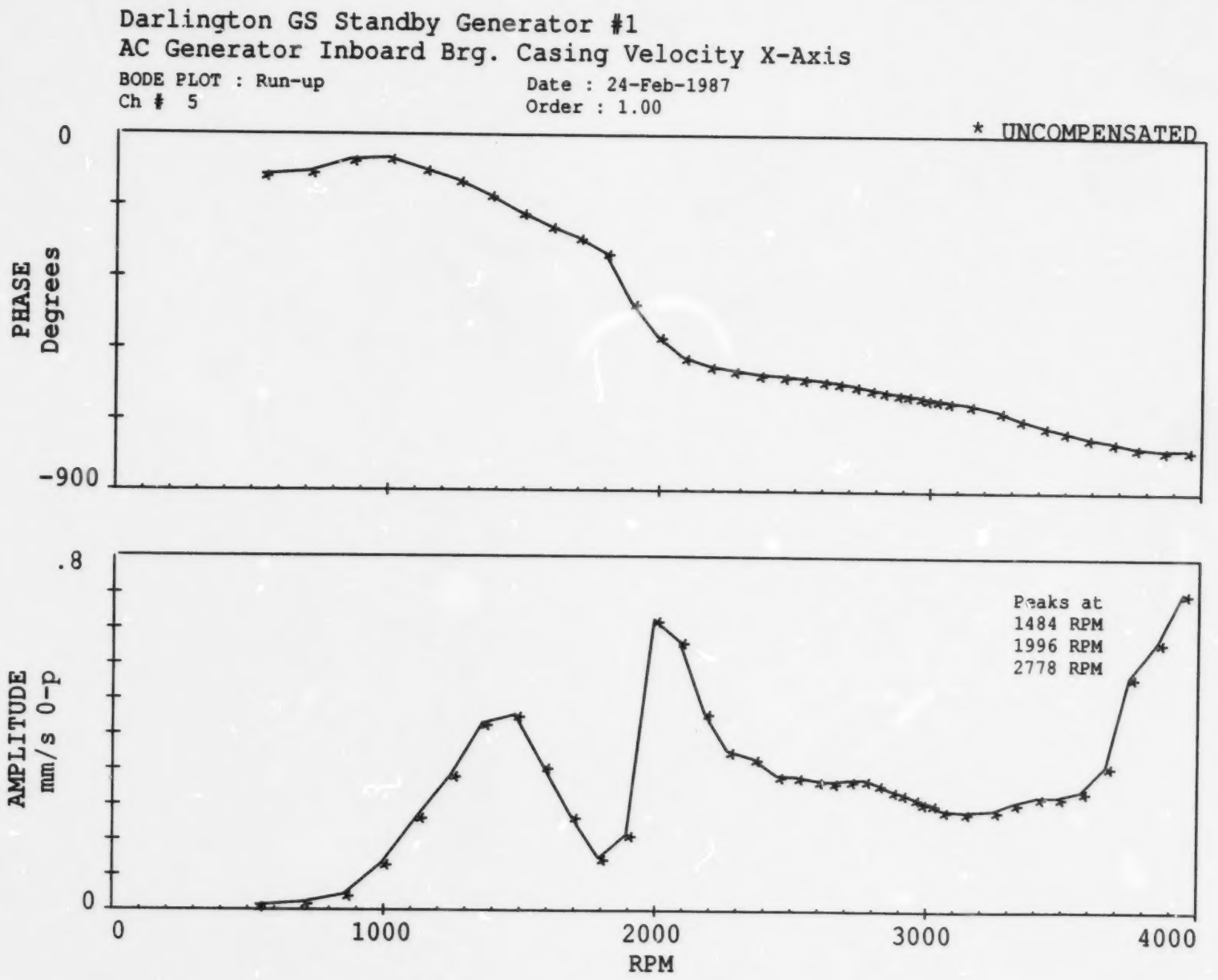


FIGURE 112

88-241

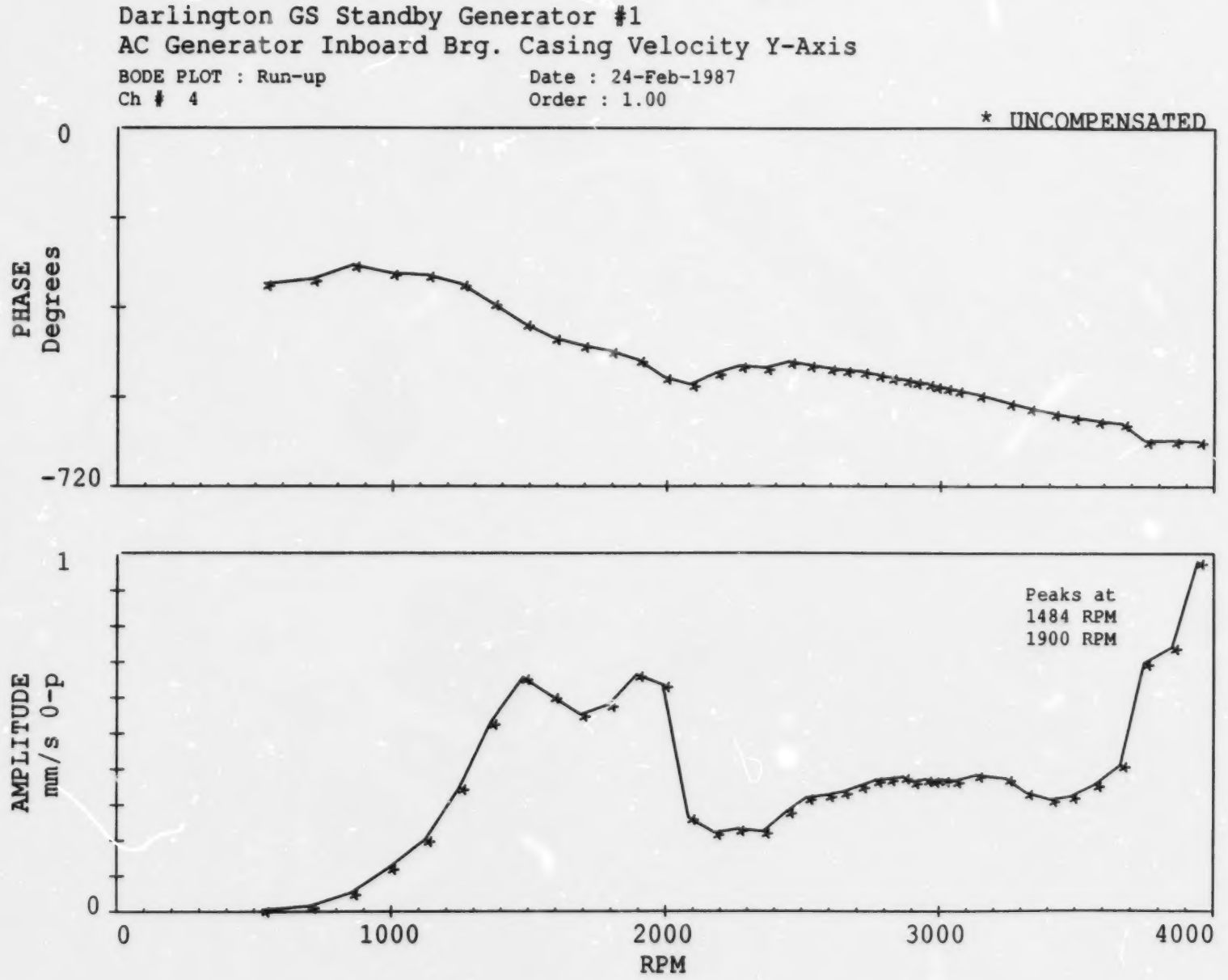


FIGURE 113

88-241

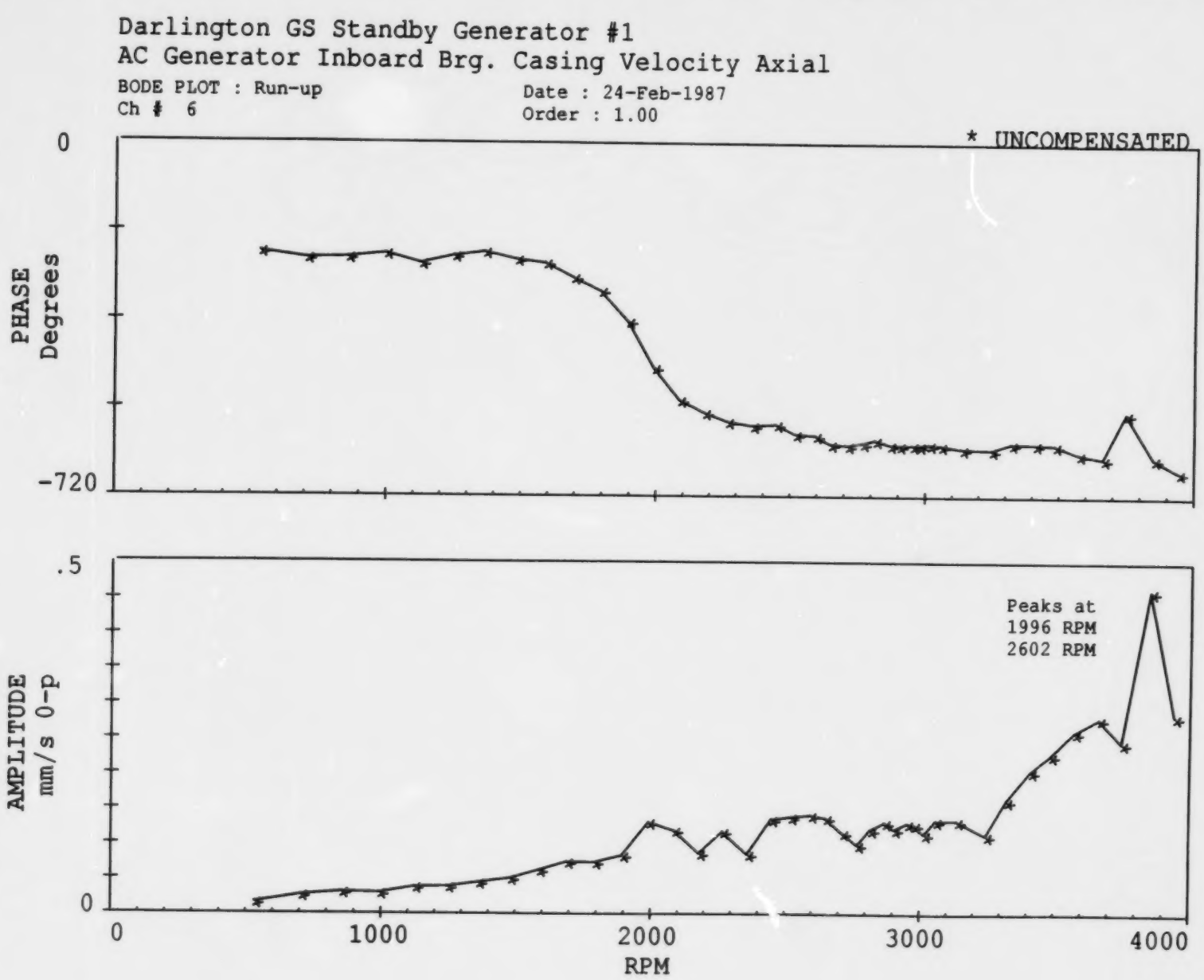


FIGURE 114

88-241

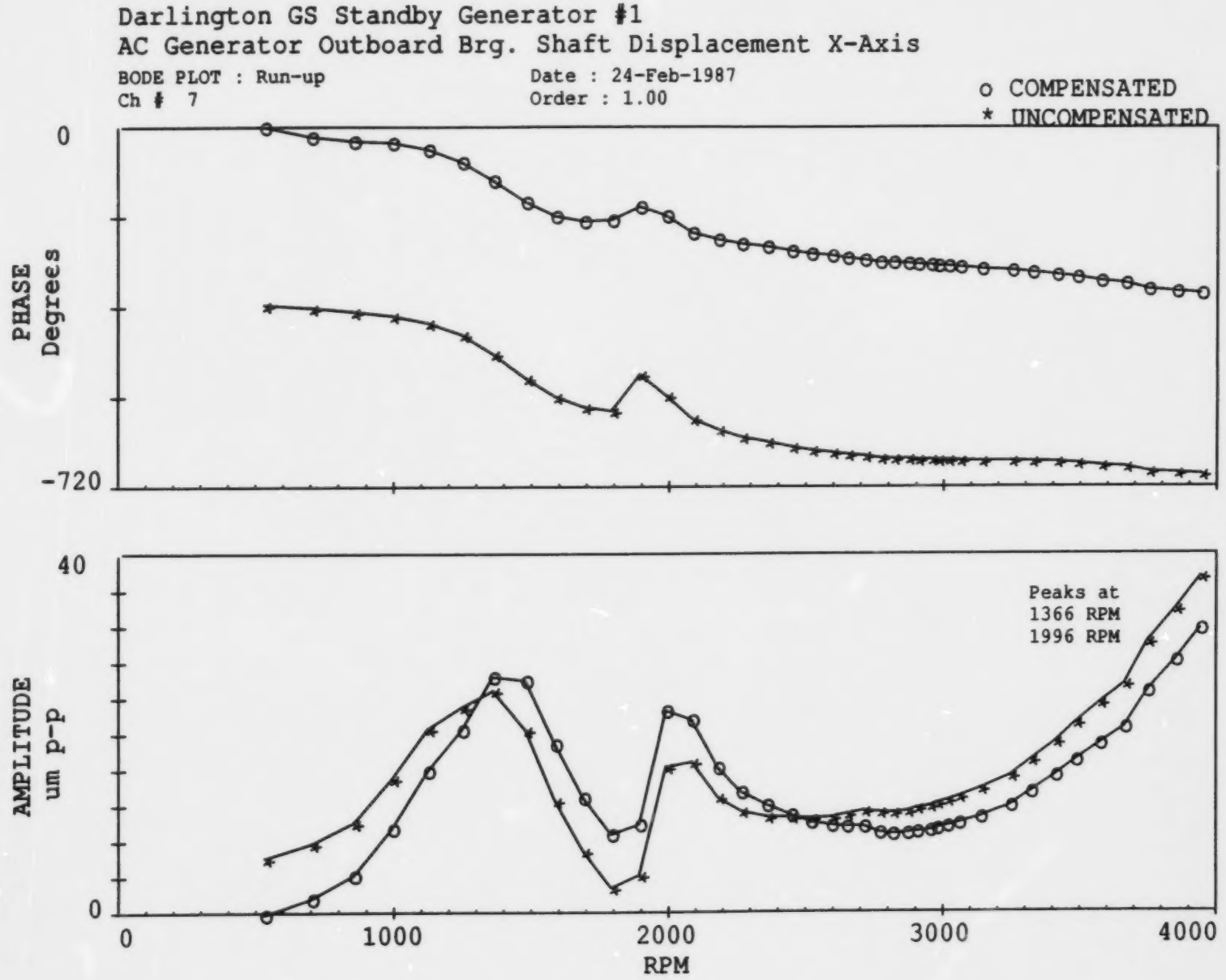


FIGURE 115

88-241

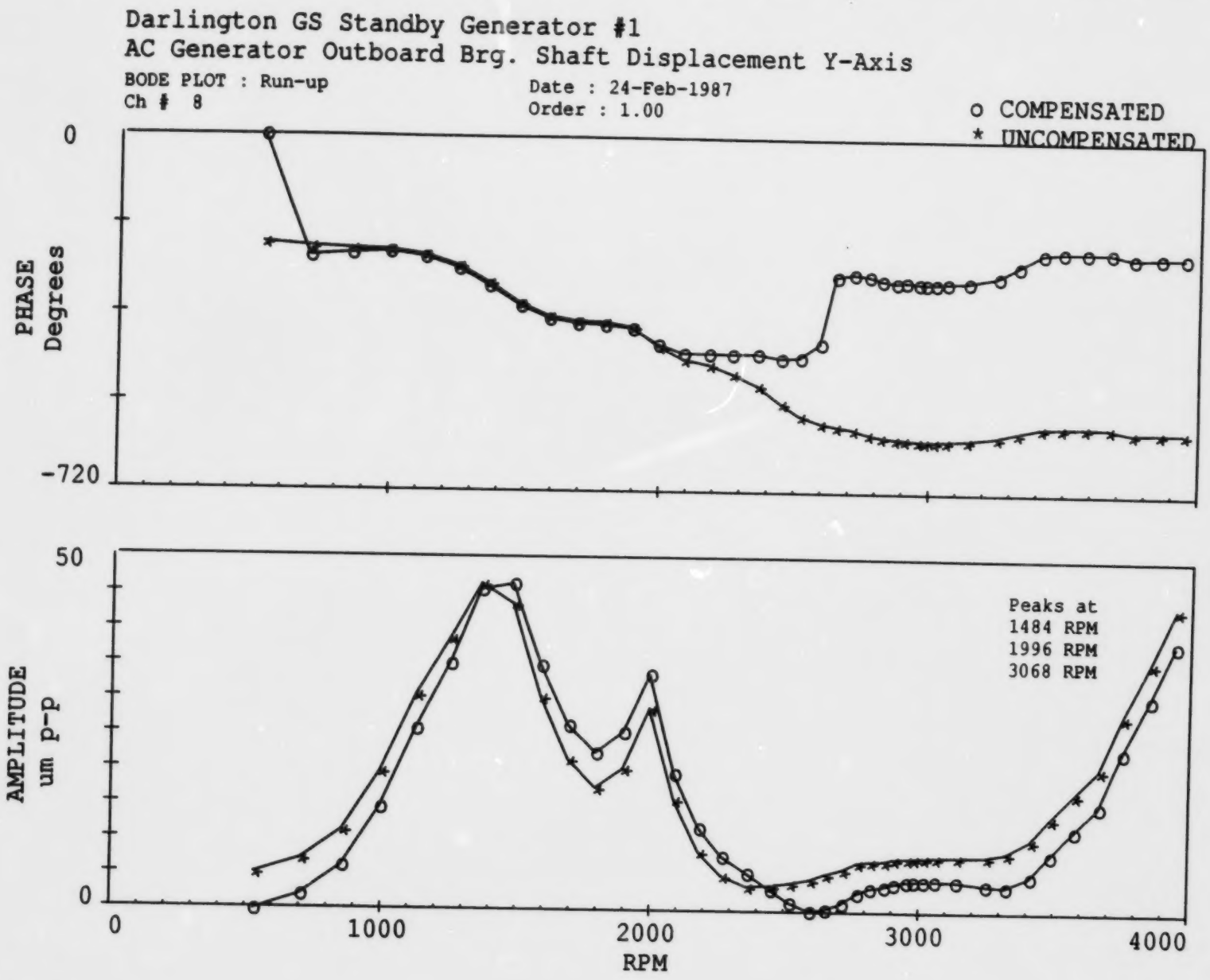


FIGURE 116
88-241

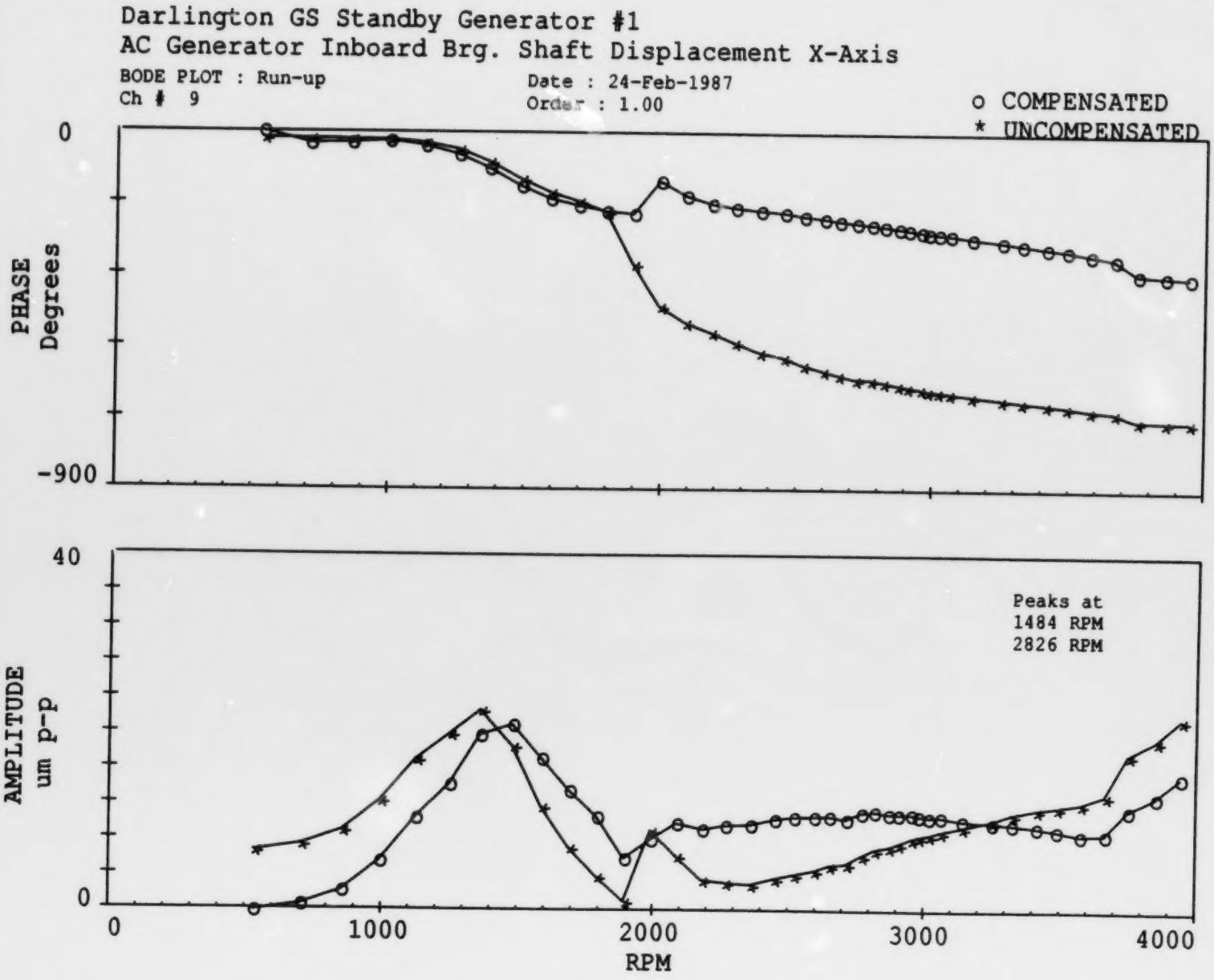


FIGURE 117

88-241

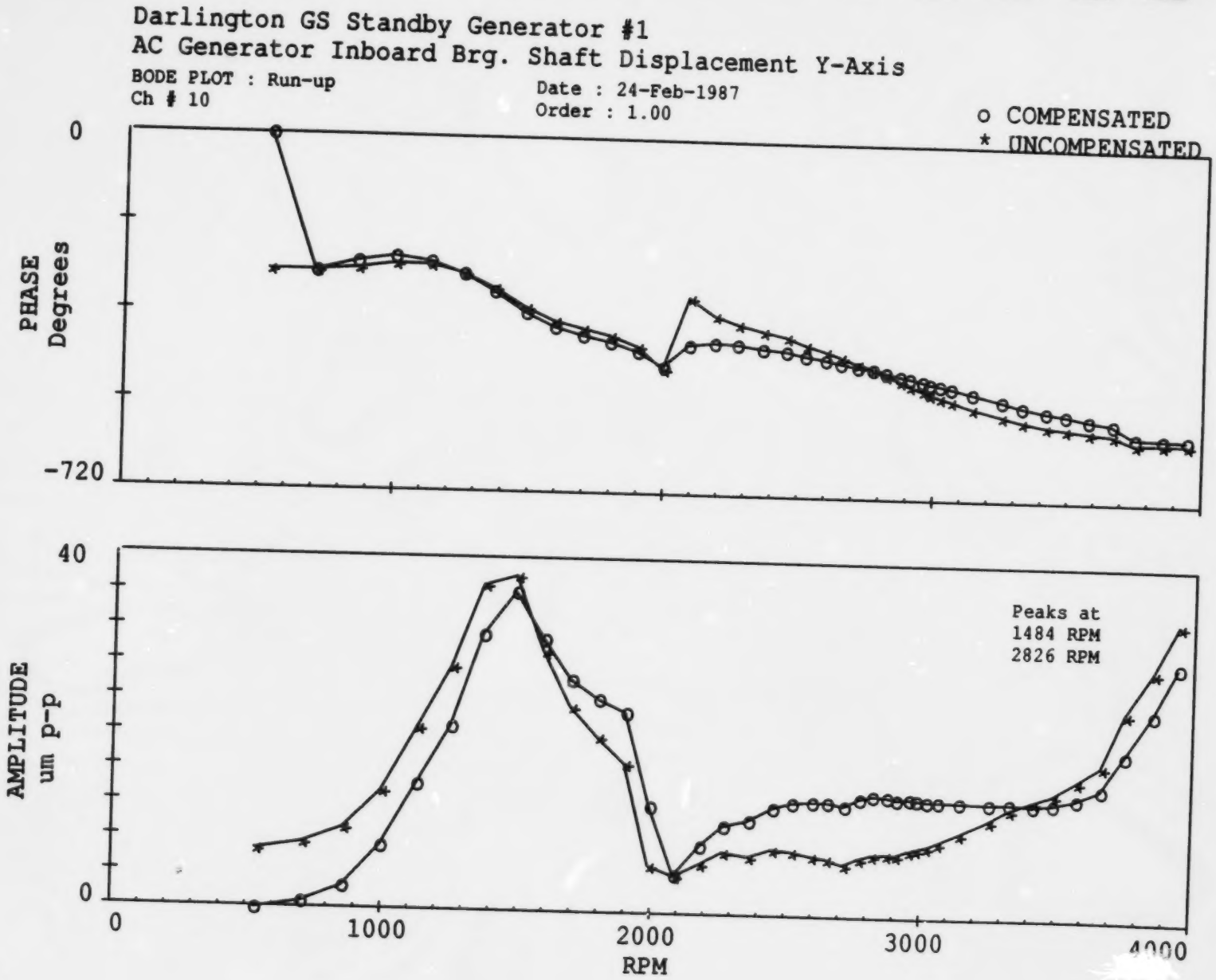


FIGURE 118

88-241

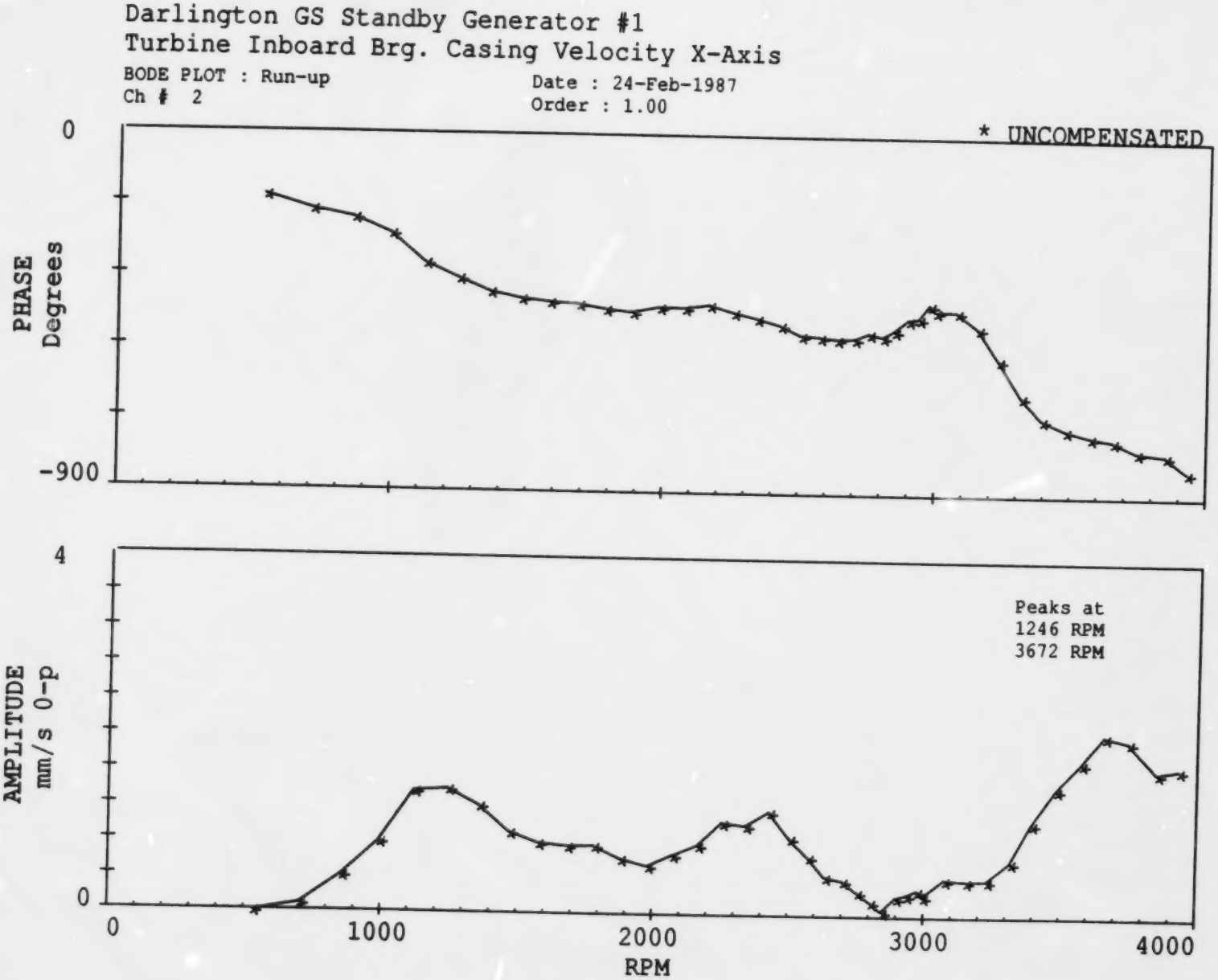


FIGURE 119

88-241

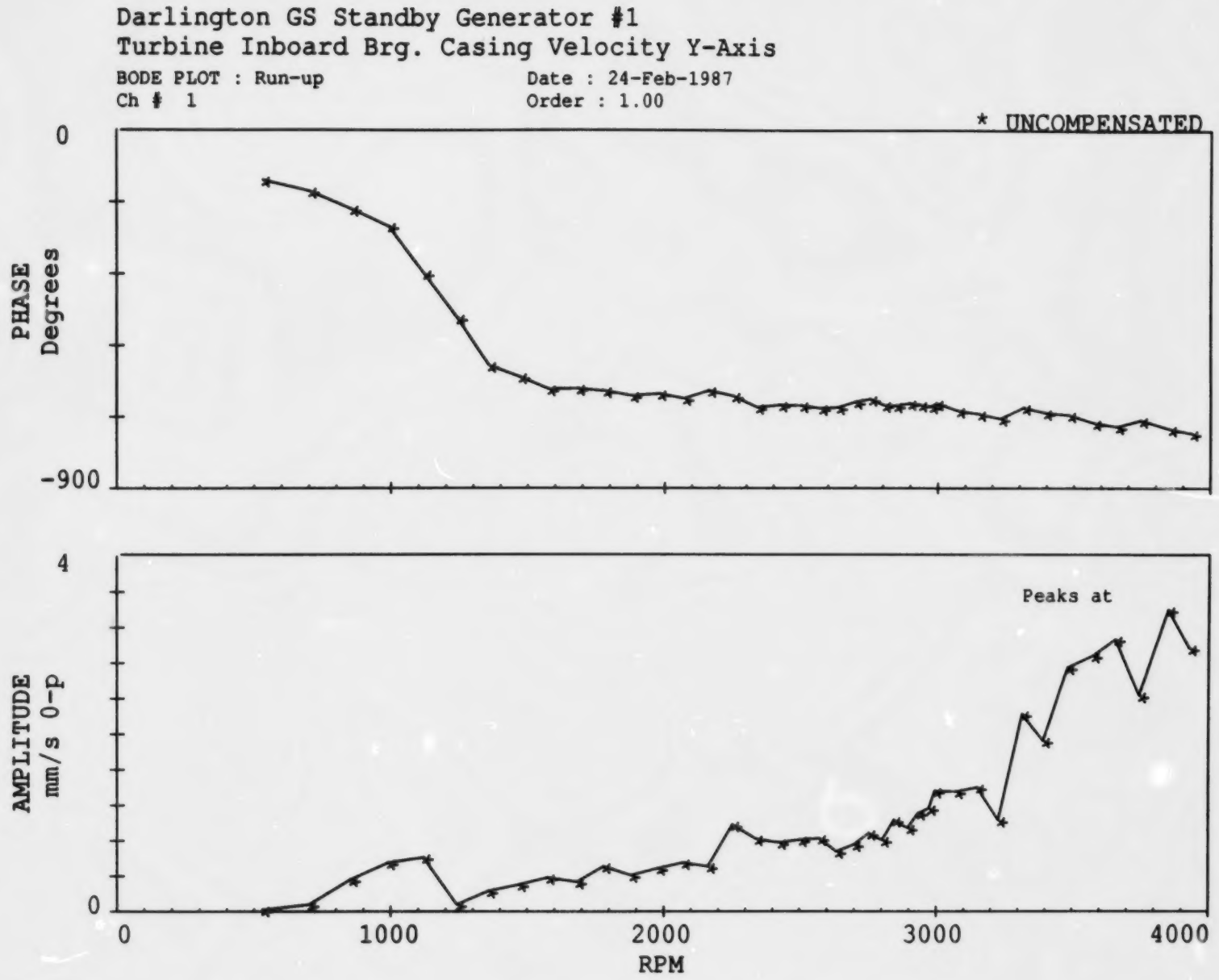


FIGURE 120

88-241

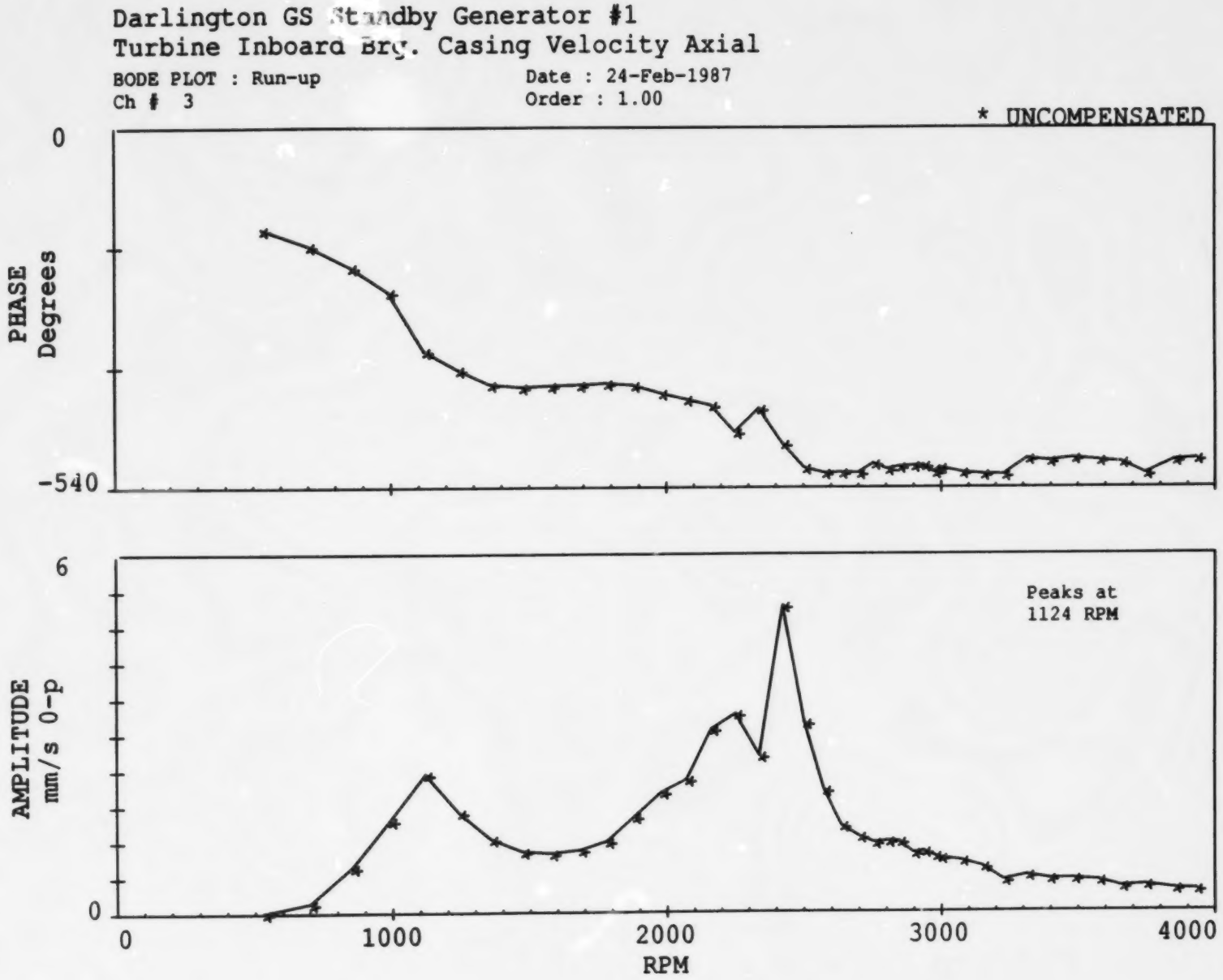


FIGURE 121
88-241

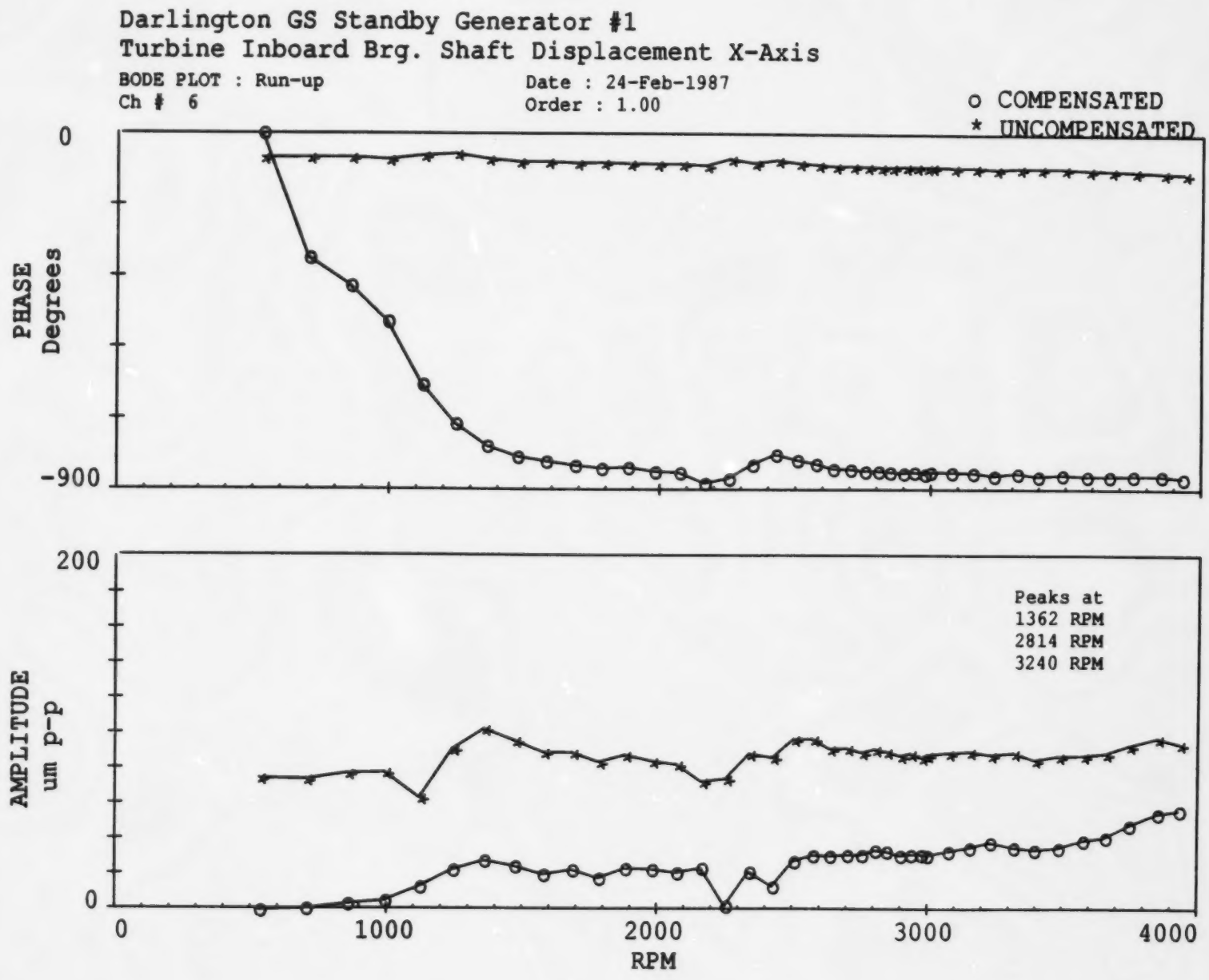


FIGURE 122
88-241

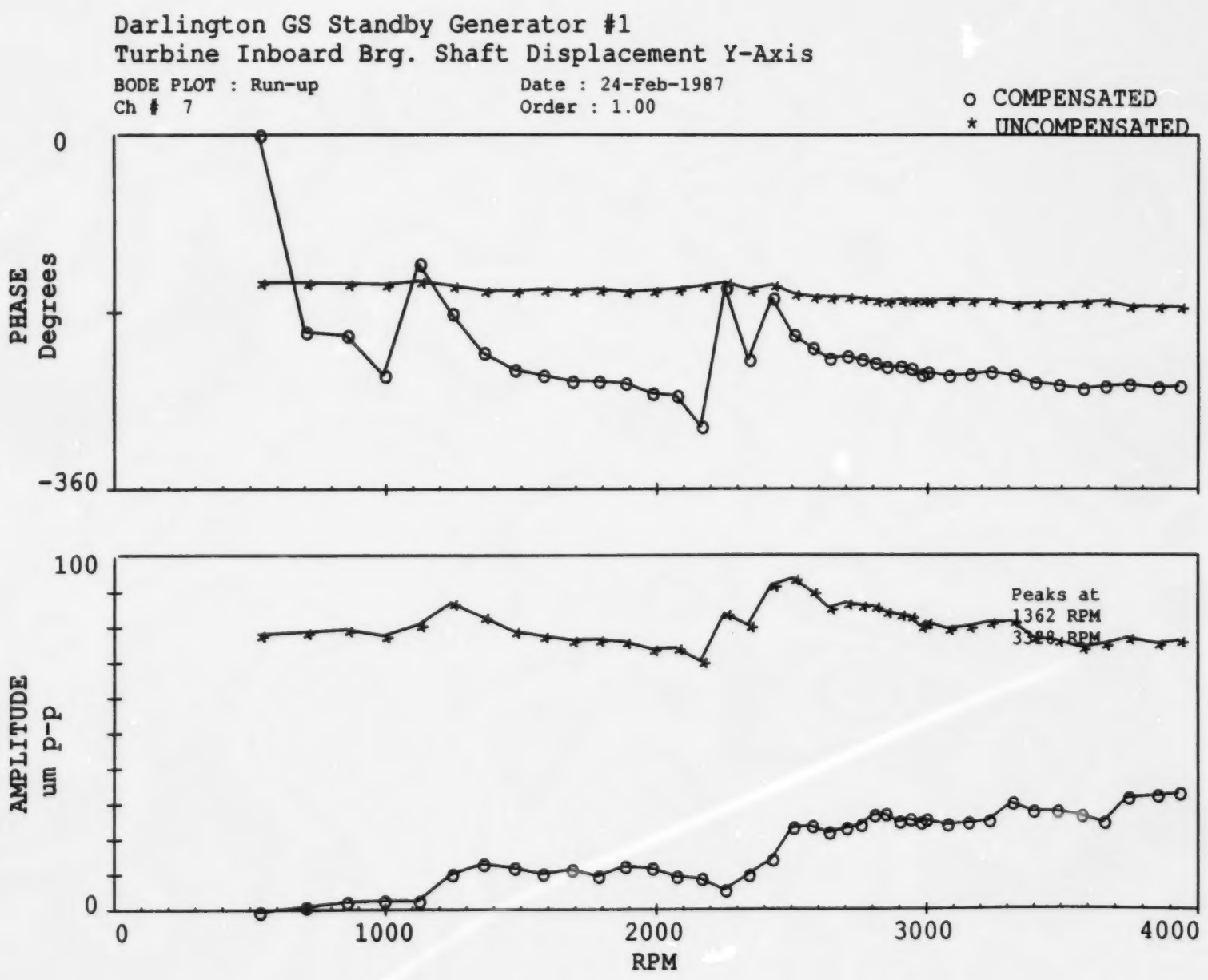


FIGURE 123

88-241

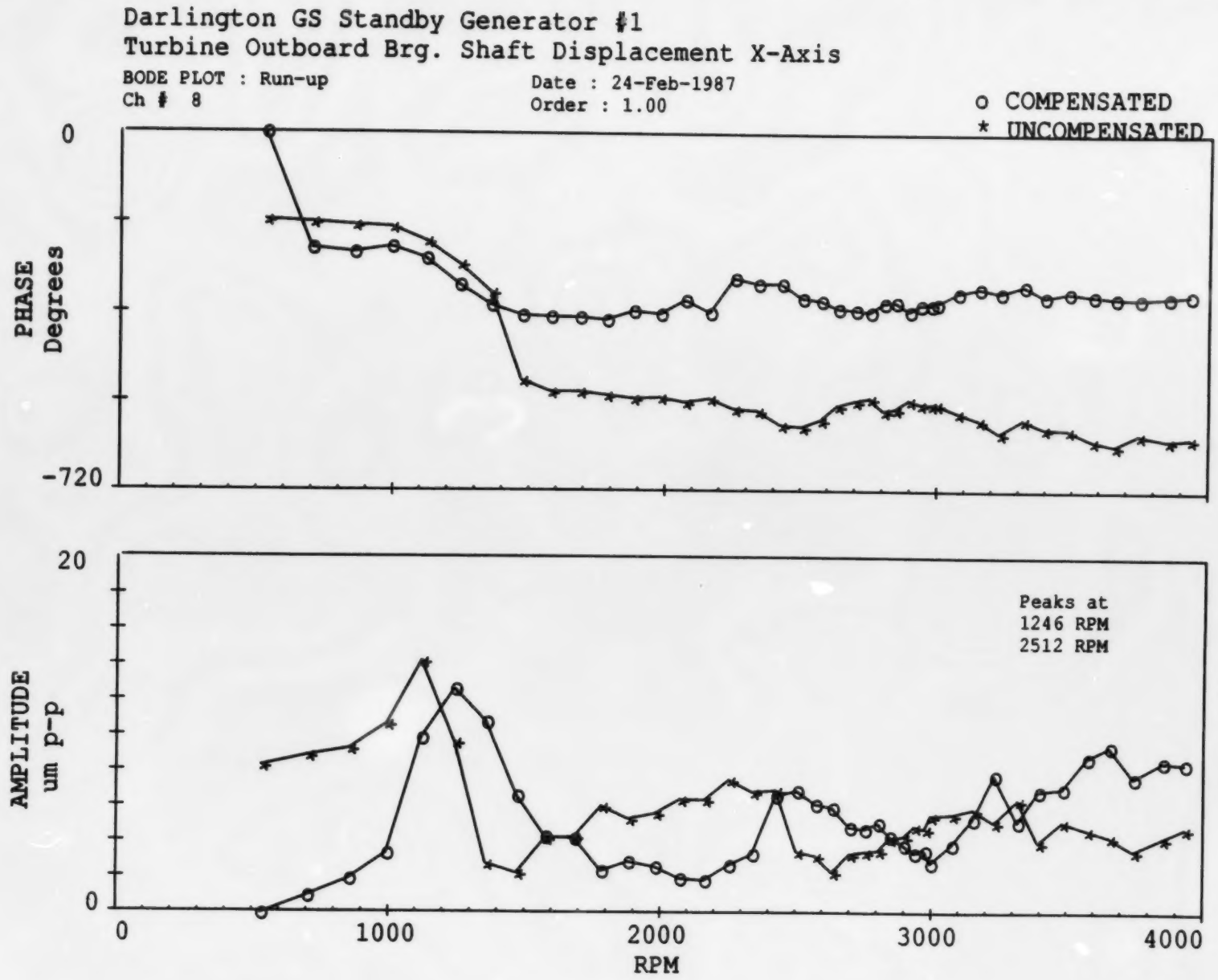


FIGURE 124
88-241

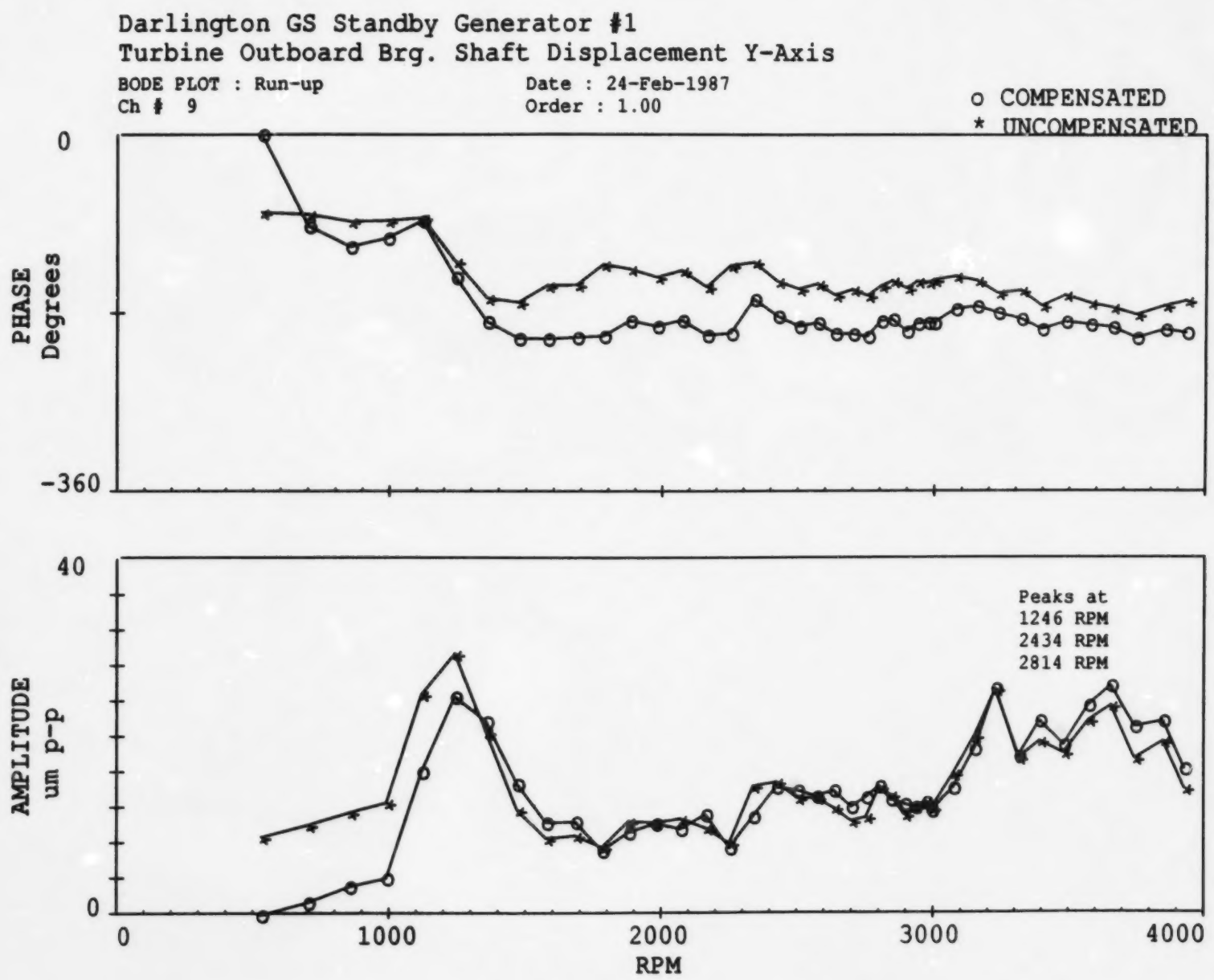


FIGURE 125
88-241

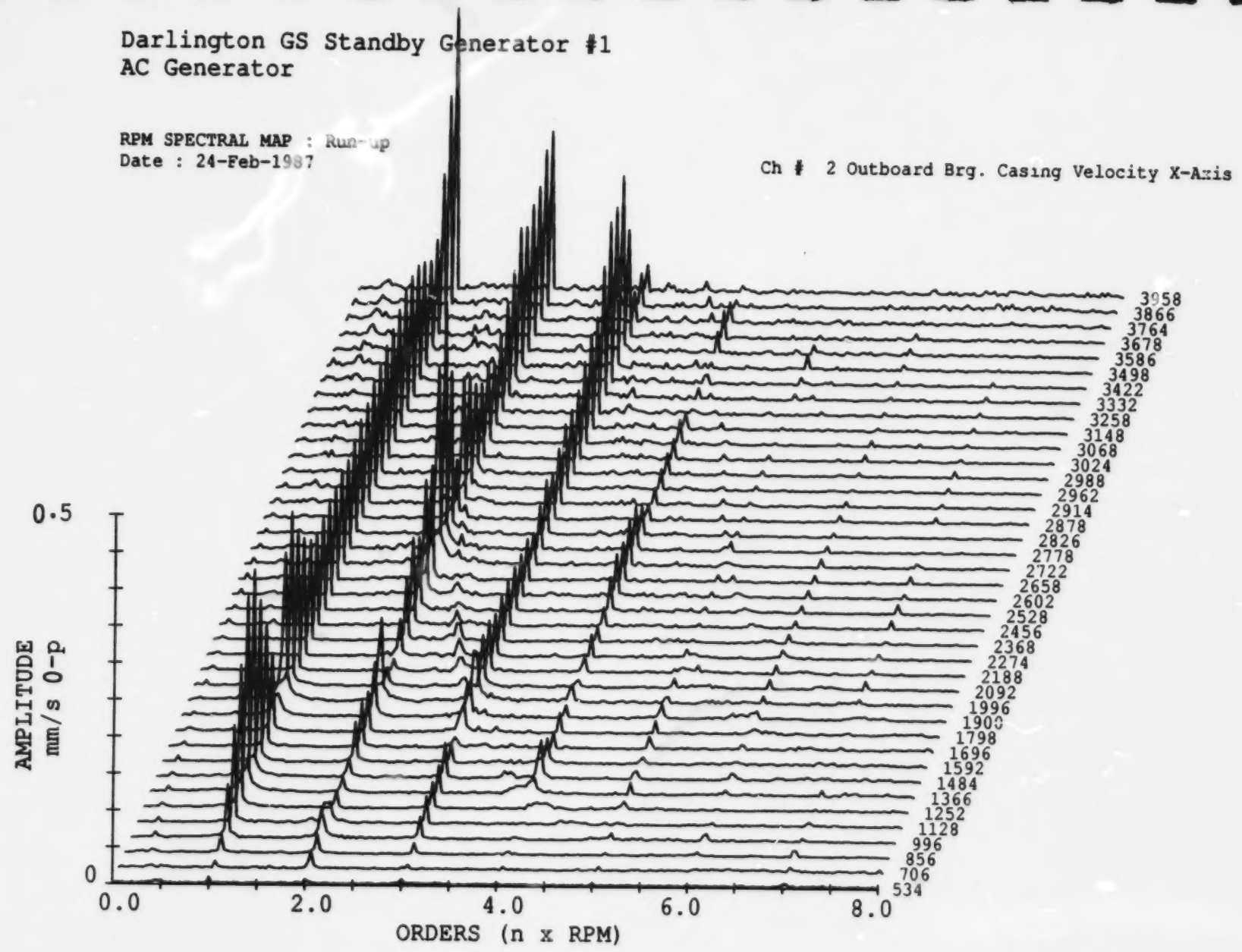


FIGURE 126

88-241

Darlington GS Standby Generator #1
AC Generator

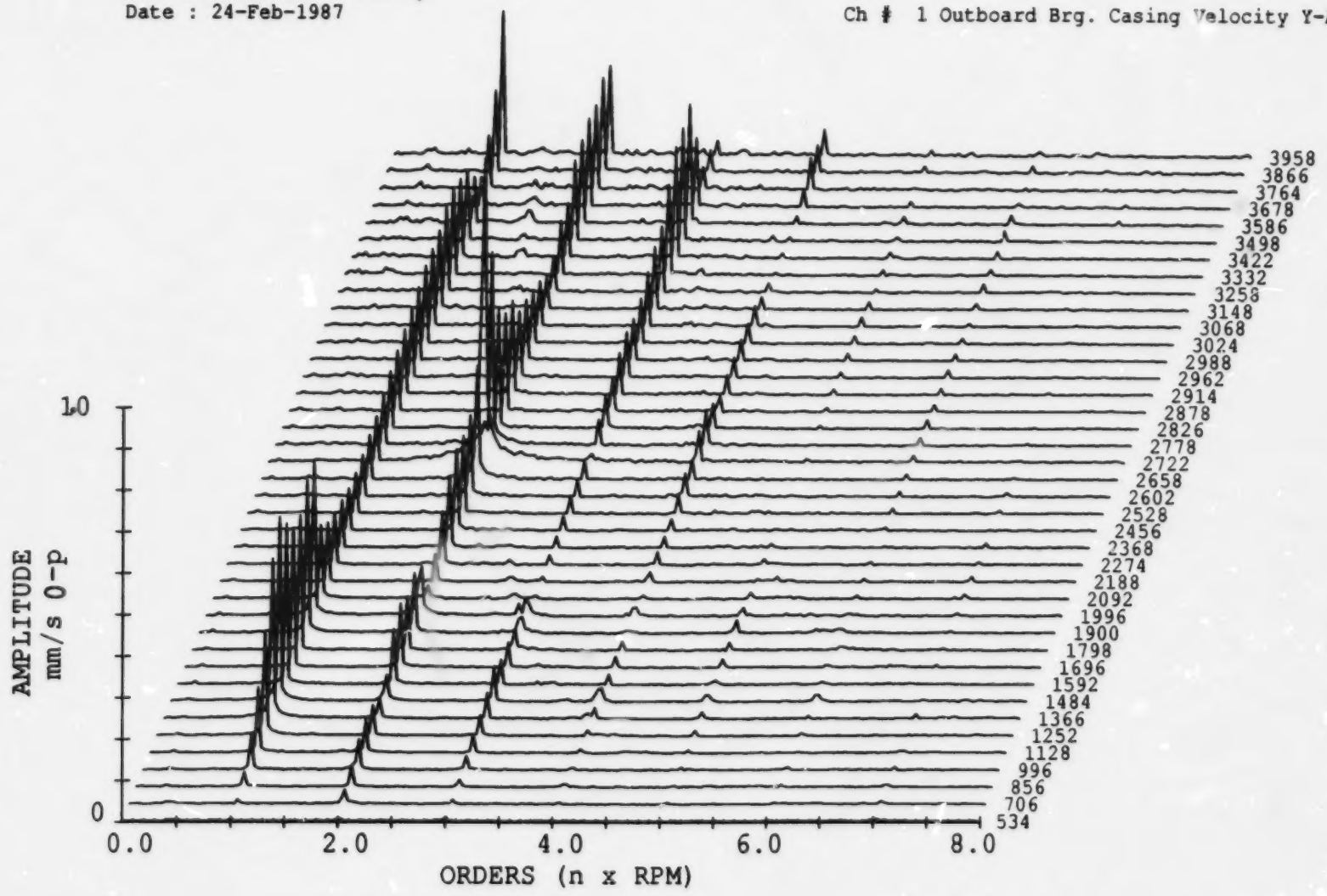


FIGURE 127
88-241

Darlington GS Standby Generator #1
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 24-Feb-1987

Ch # 3 Outboard Brg. Casing Velocity Axial

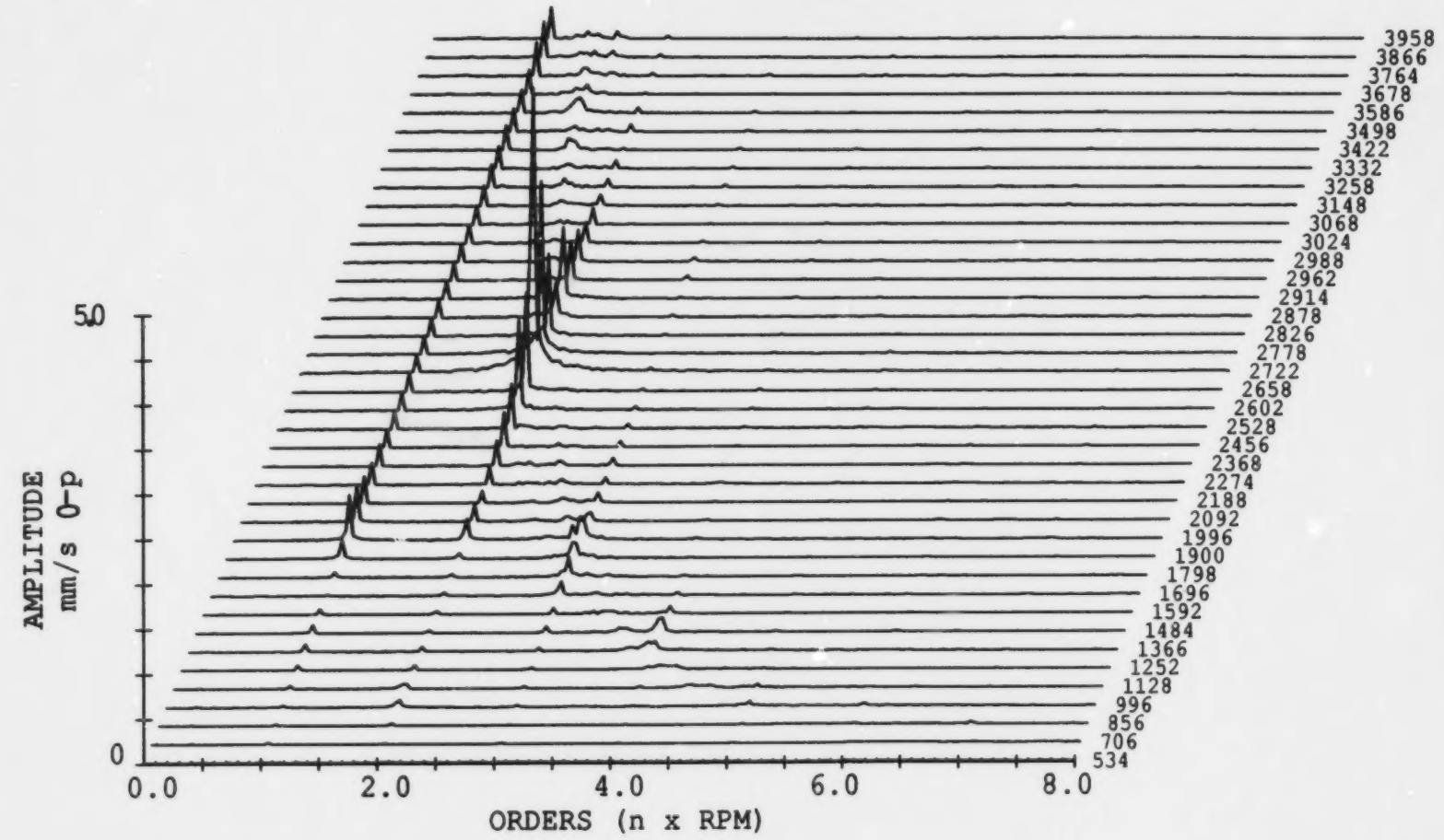


FIGURE 128
88-241

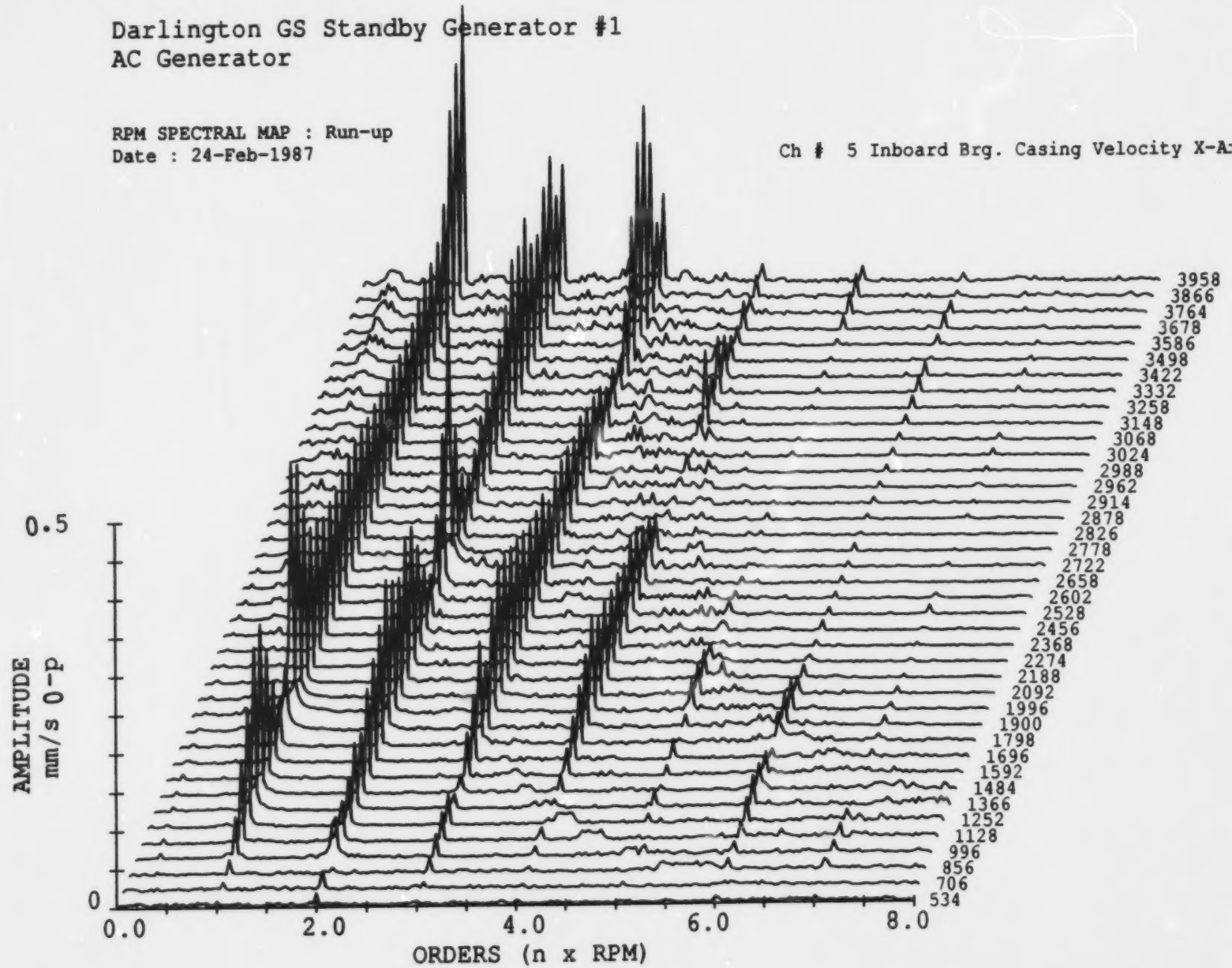


FIGURE 129
88-241

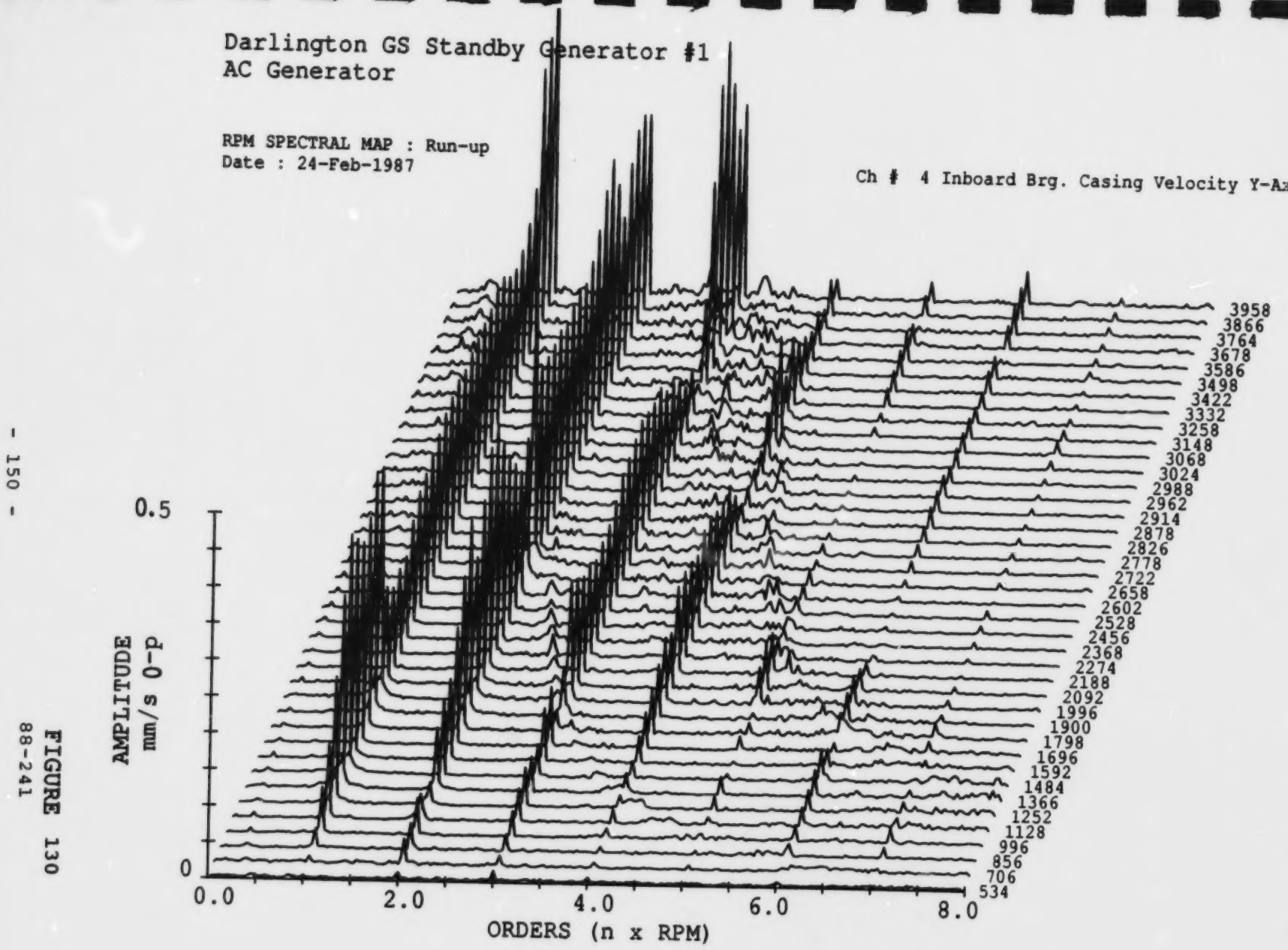


FIGURE 130
88-241

Darlington GS Standby Generator #1
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 24-Feb-1987

Ch # 6 Inboard Brg. Casing Velocity Axial

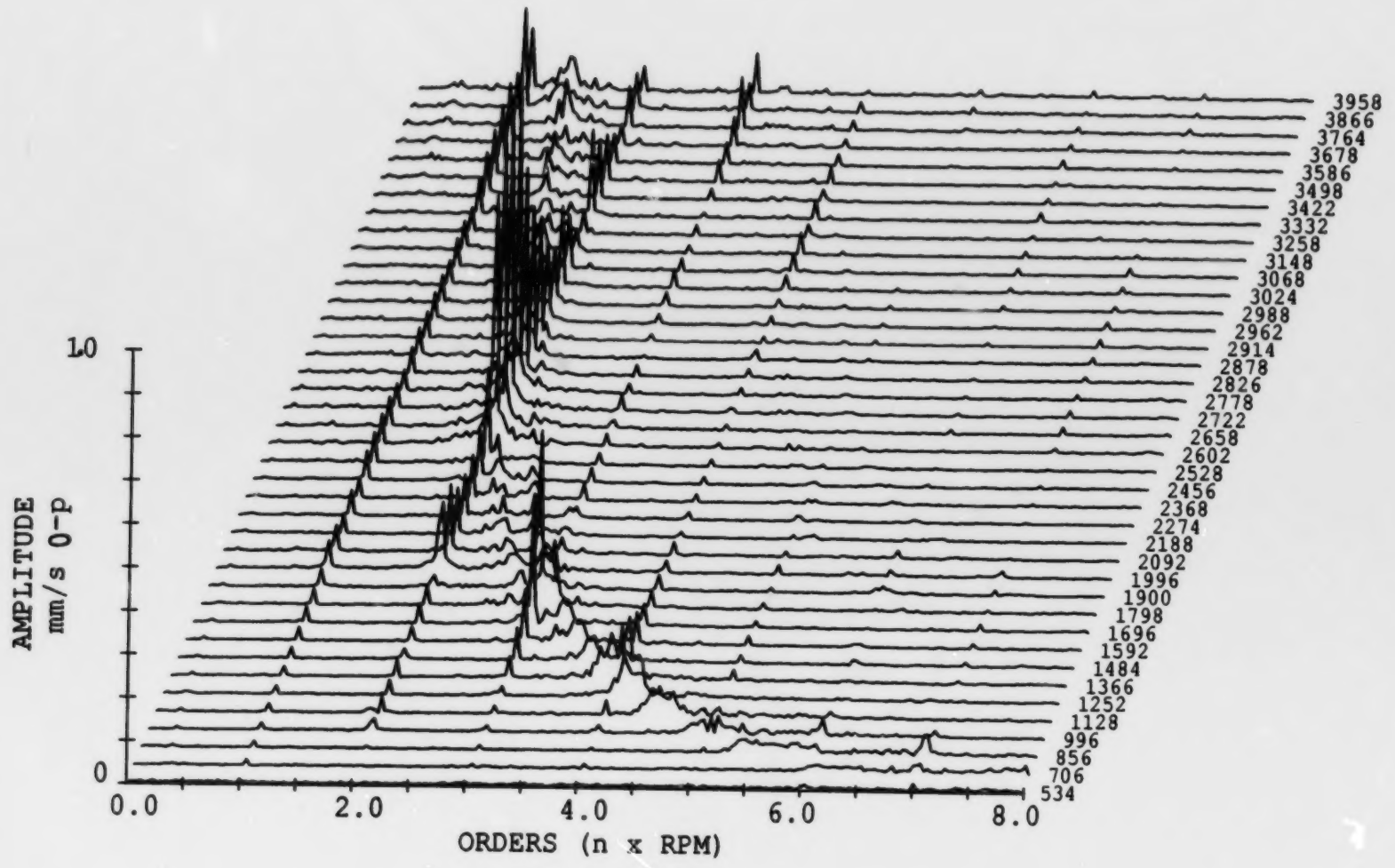


FIGURE 131

88-241

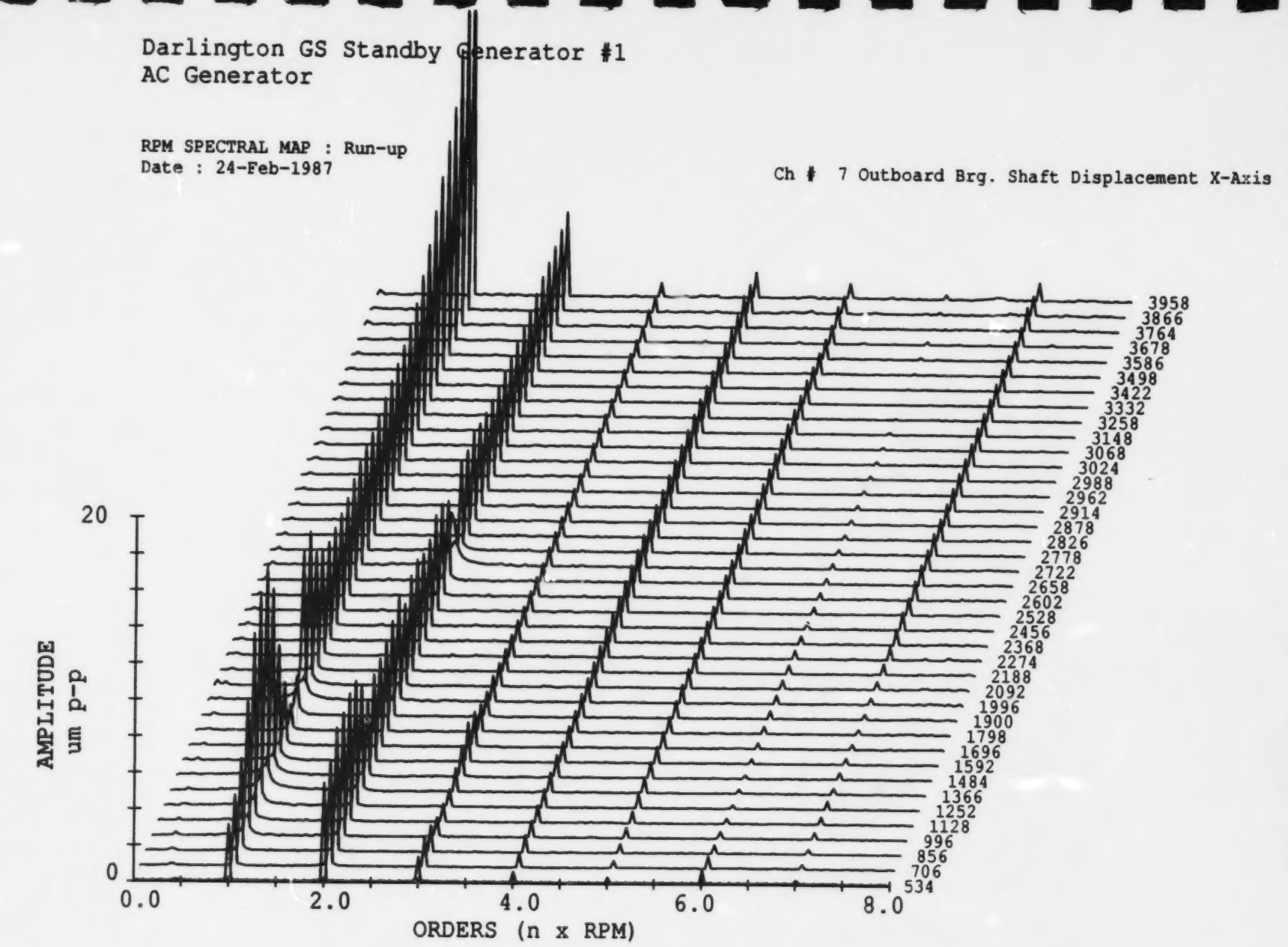


FIGURE 132
88-241

Darlington GS Standby Generator #1
AC Generator

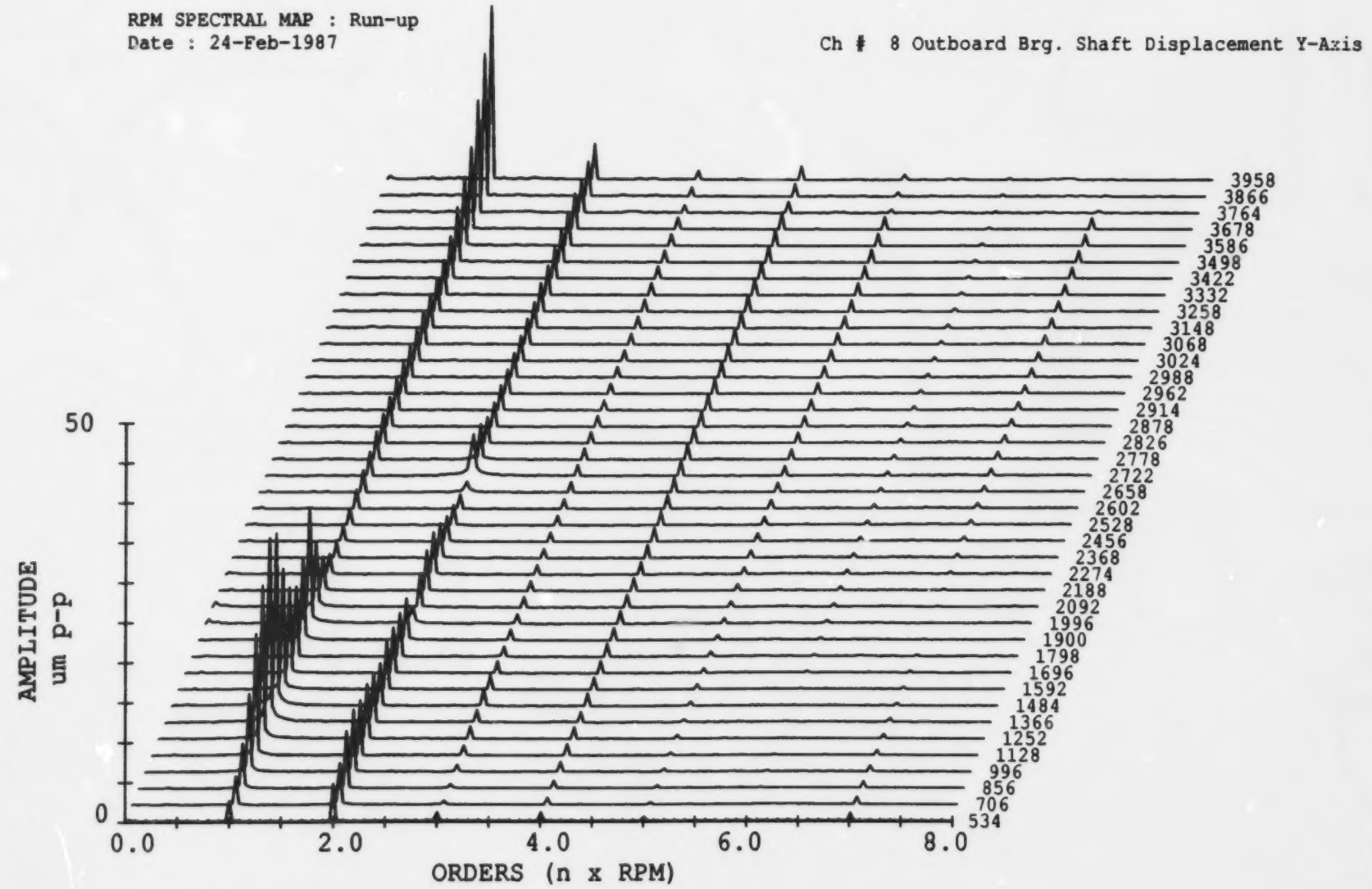


FIGURE 133

88-241

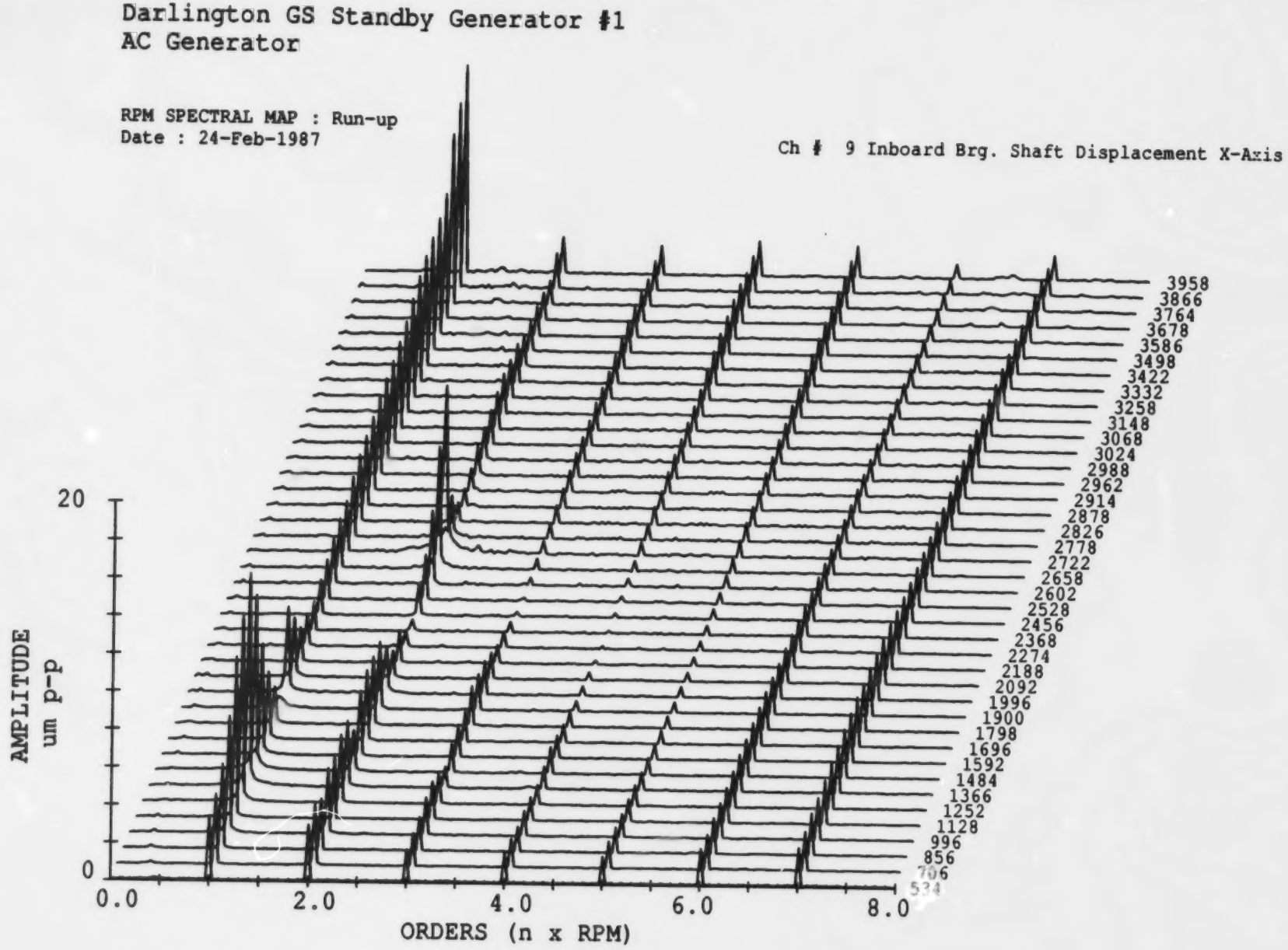


FIGURE 134

88-241

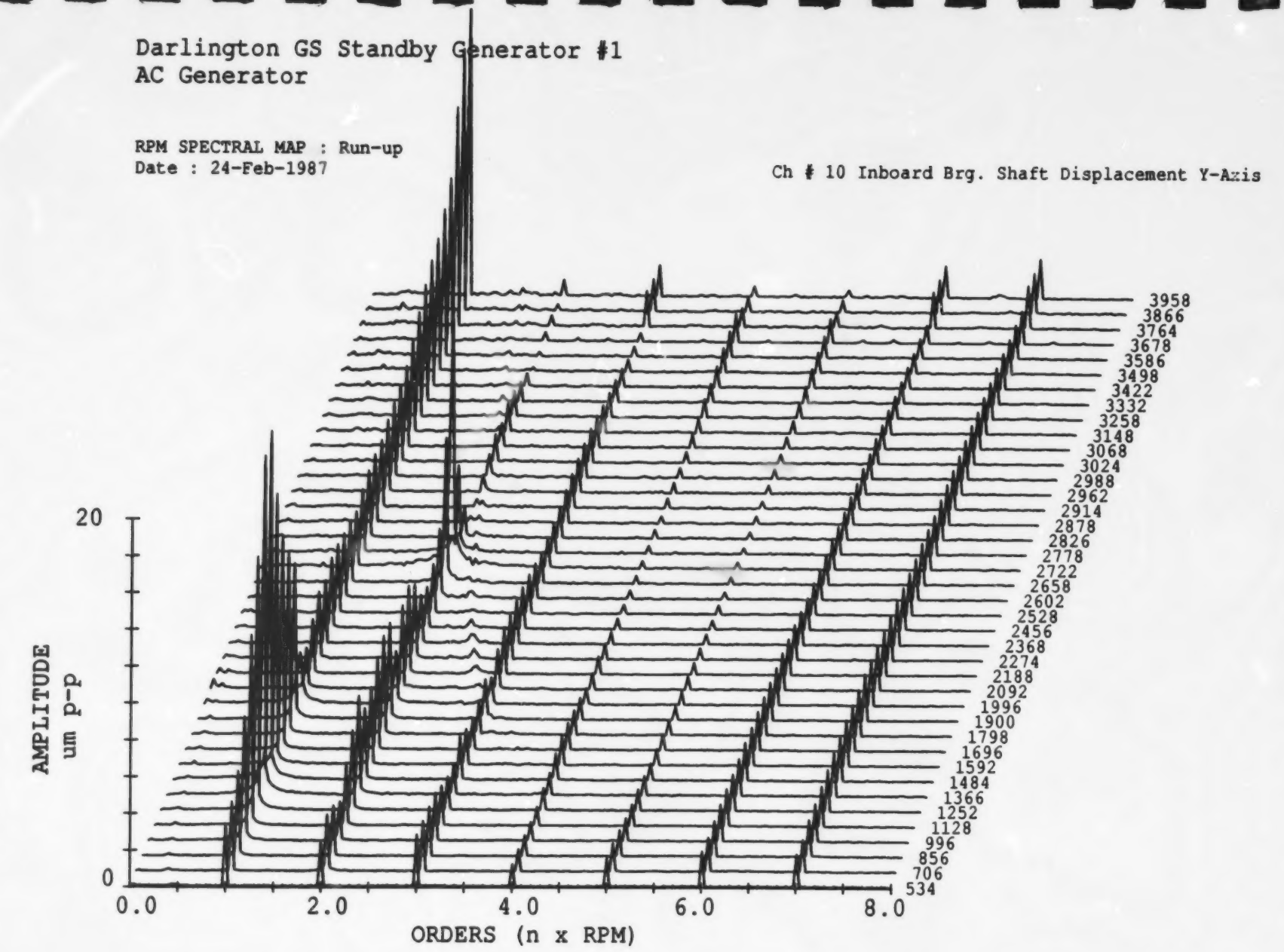


FIGURE 135

88-241

Darlington GS Standby Generator #1
Turbine

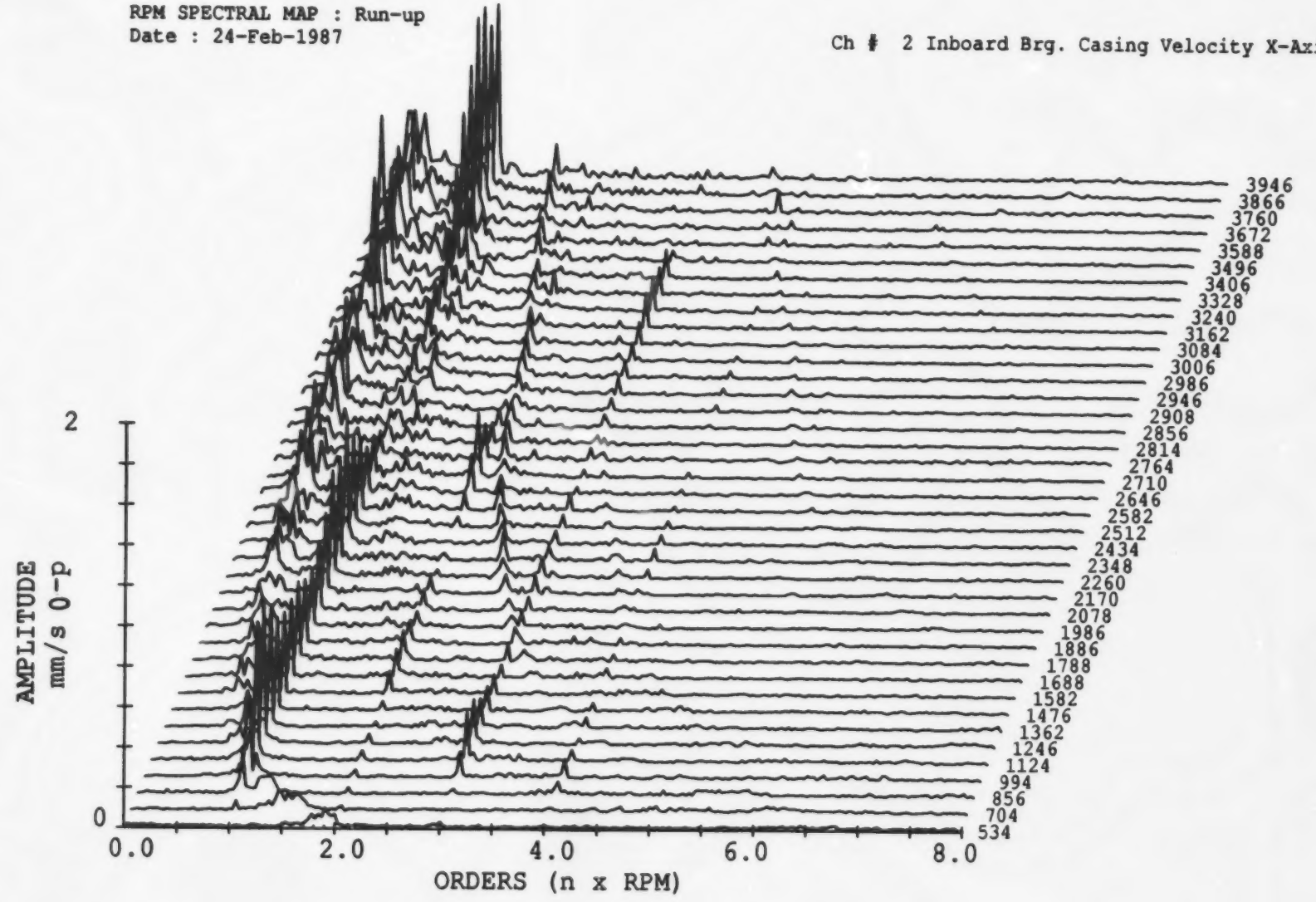


FIGURE 136

88-241

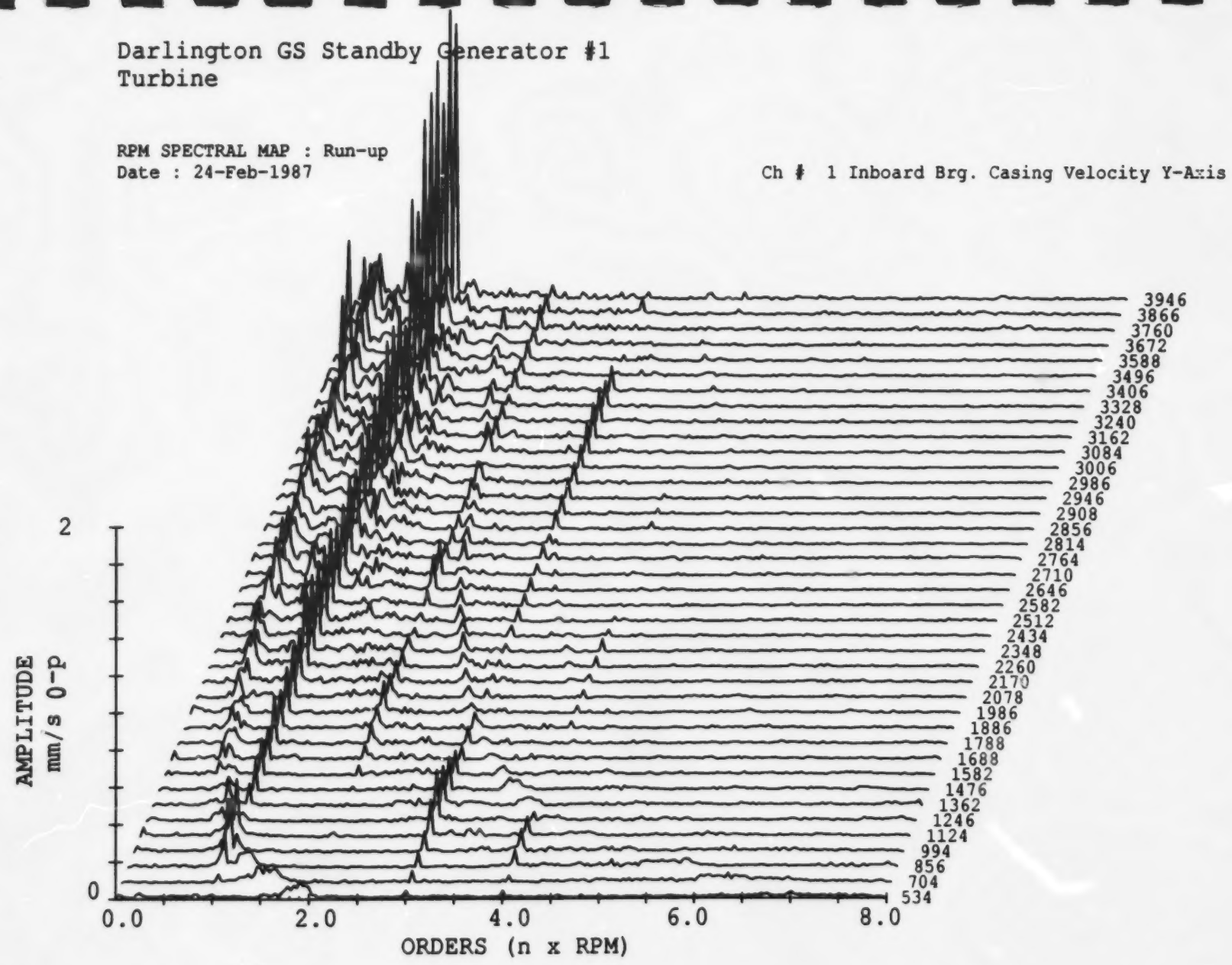


FIGURE 137
88-241

Darlington GS Standby Generator #1
Turbine

RPM SPECTRAL MAP : Run-up
Date : 24-Feb-1987

Ch # 3 Inboard Brg. Casing Velocity Axial

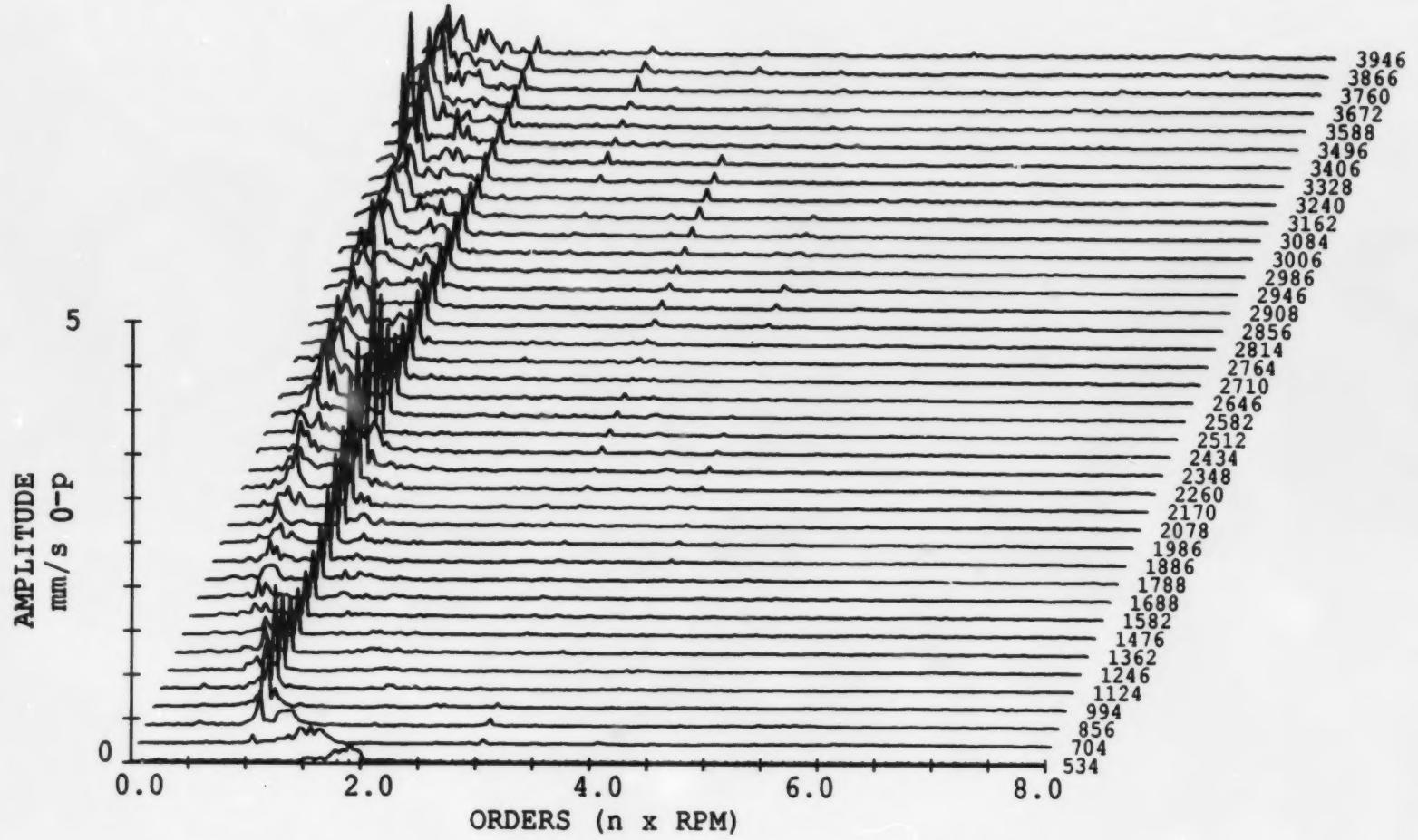


FIGURE 138

88-241

Darlington GS Standby Generator #1
Turbine

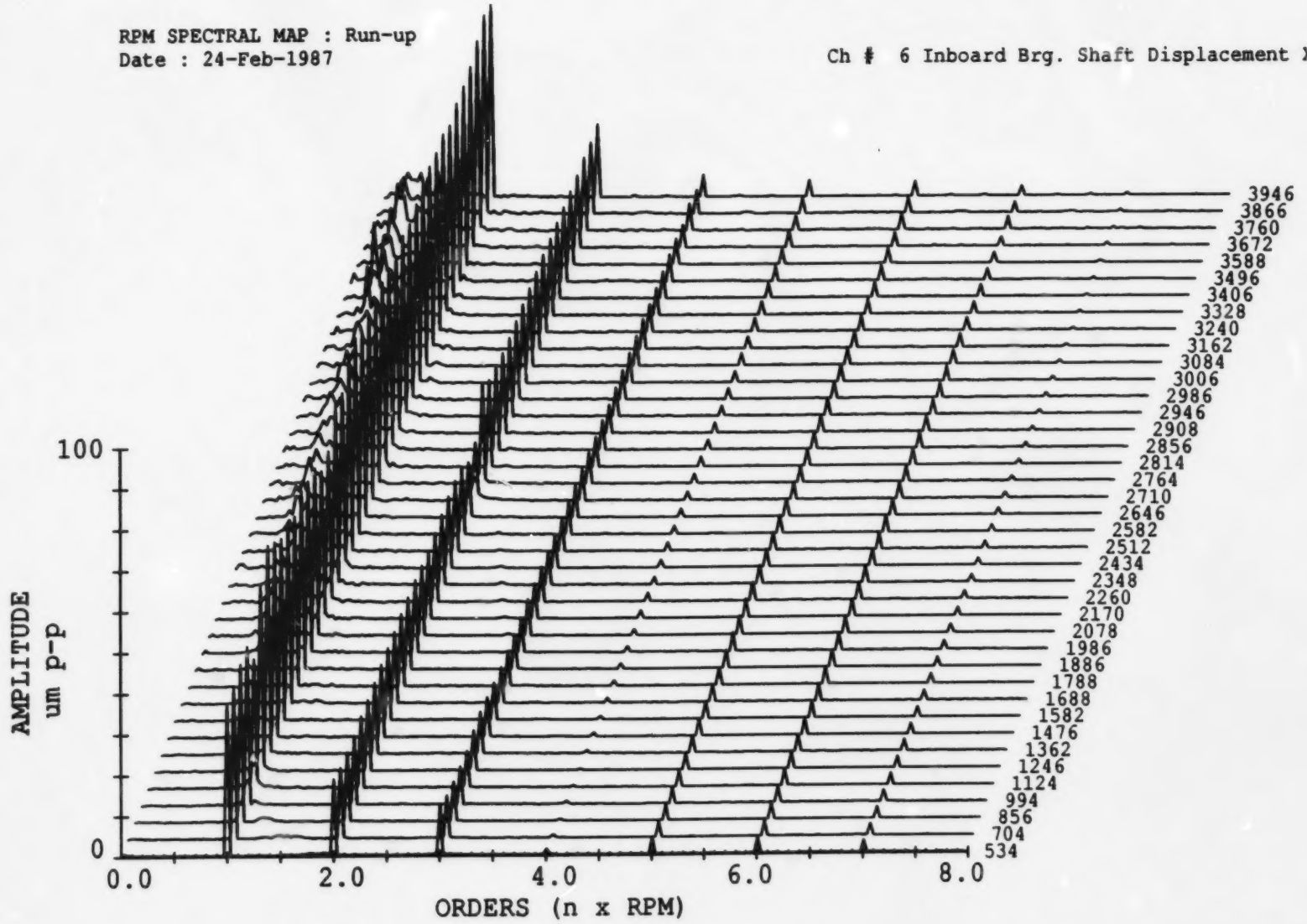


FIGURE 139
88-241

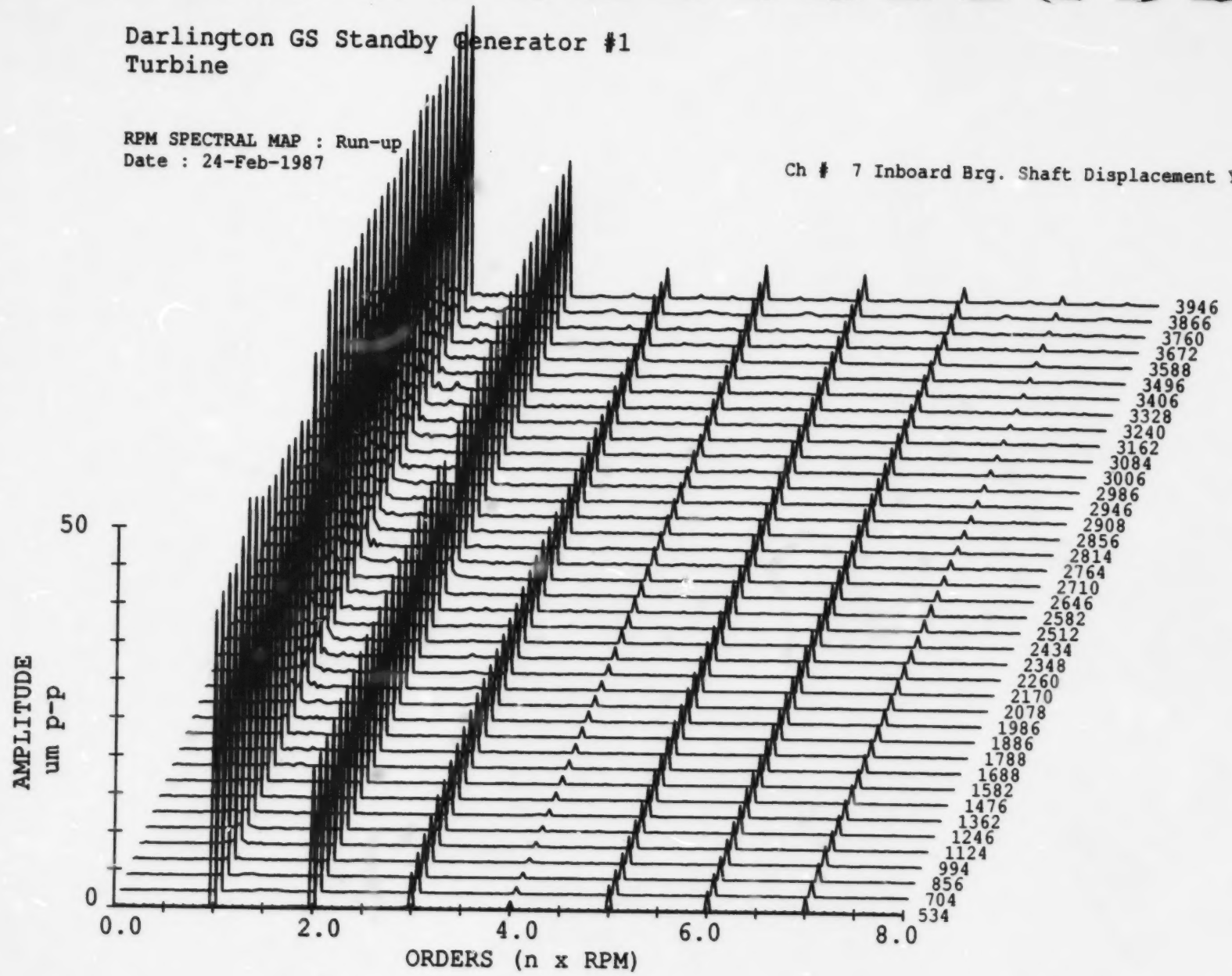


FIGURE 140
88-241

Darlington GS Standby Generator #1
Turbine

RPM SPECTRAL MAP : Run-up
Date : 24-Feb-1987

Ch # 8 Outboard Brg. Shaft Displacement X-Axis

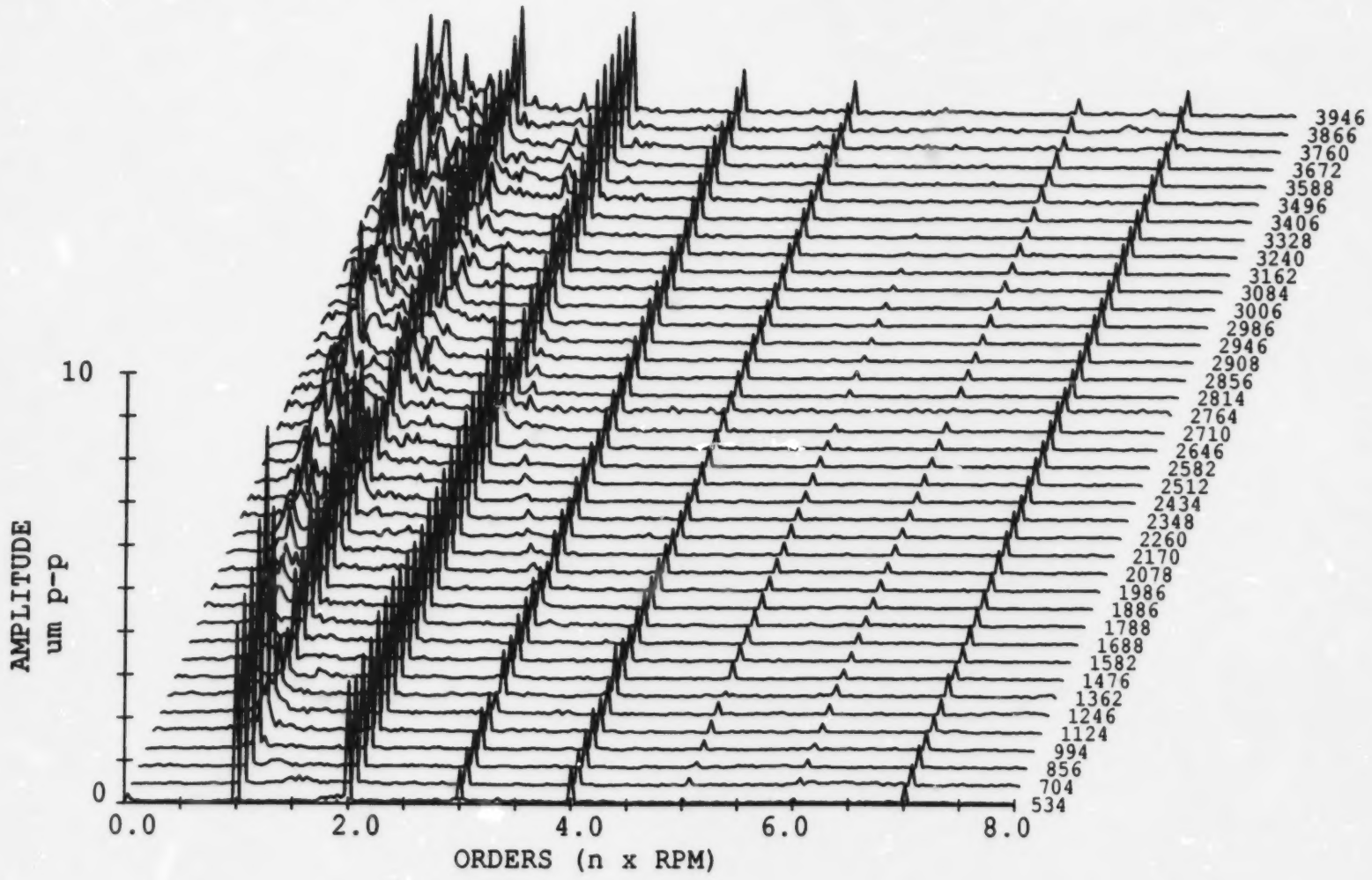


FIGURE 141
88-241

Darlington GS Standby Generator #1
Turbine

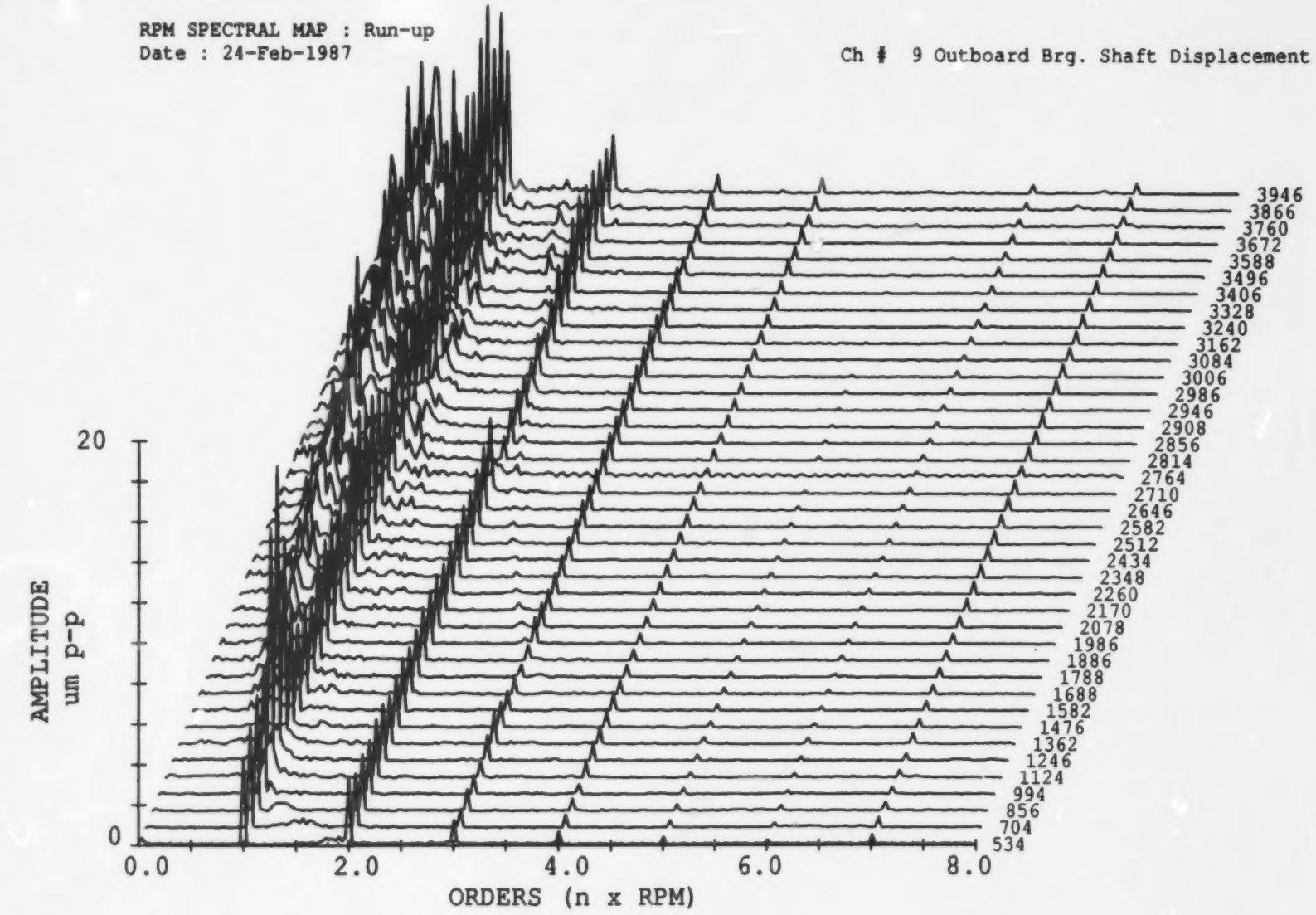


FIGURE 142
88-241

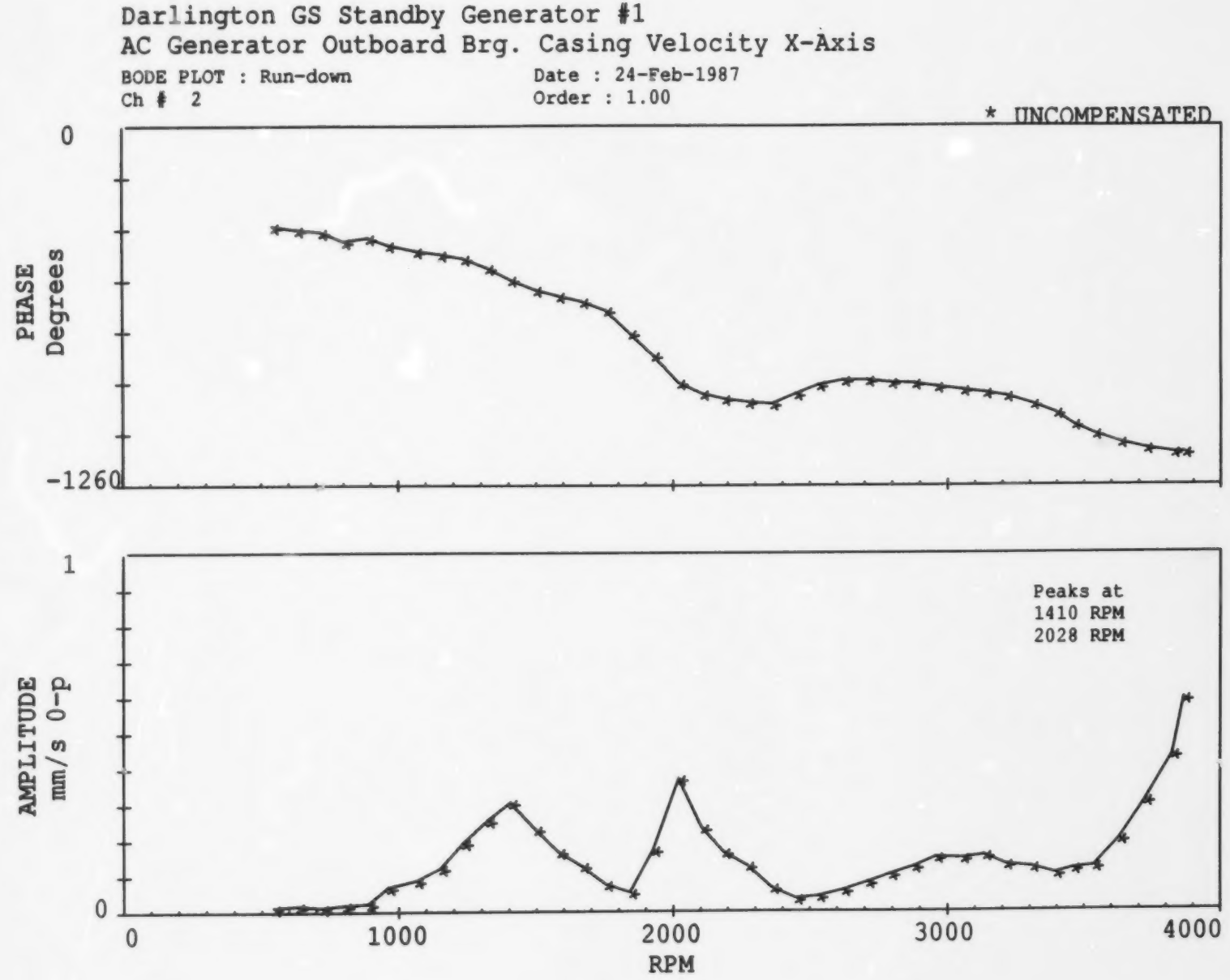


FIGURE 143
88-241

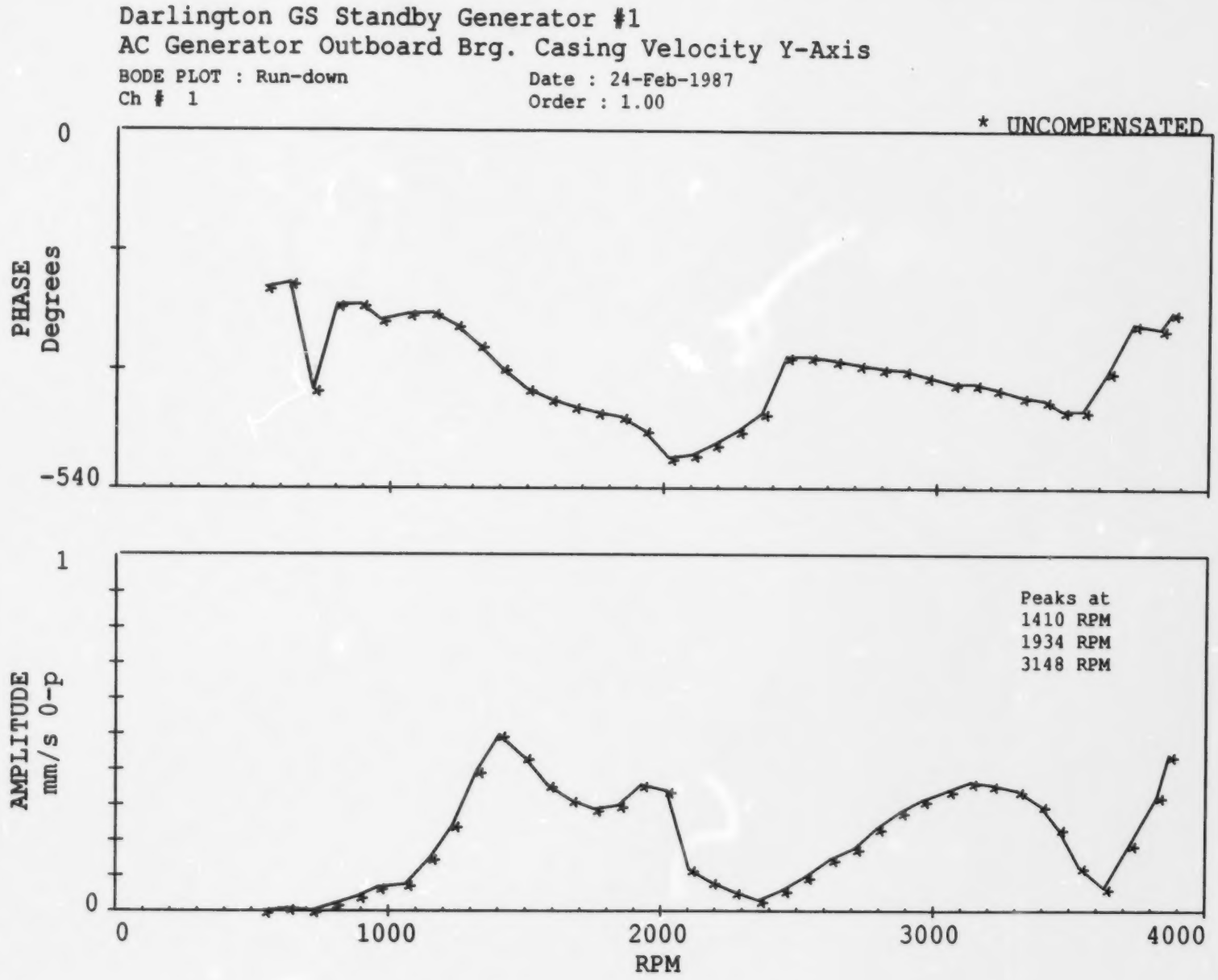


FIGURE 144
88-241

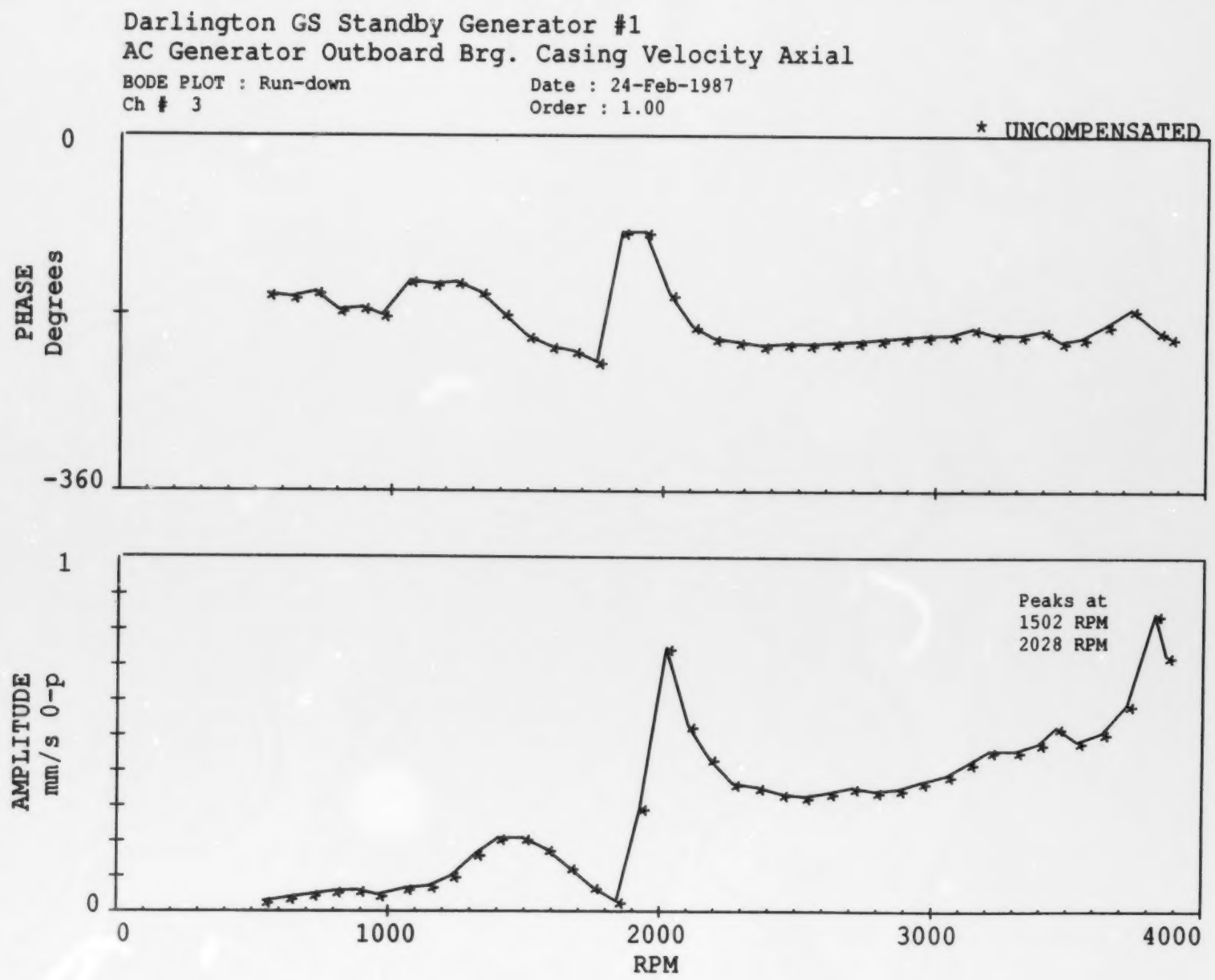


FIGURE 145
88-241

Darlington GS Standby Generator #1
AC Generator Inboard Brg. Casing Velocity X-Axis

BODE PLOT : Run-down
Ch # 5

Date : 24-Feb-1987
Order : 1.00

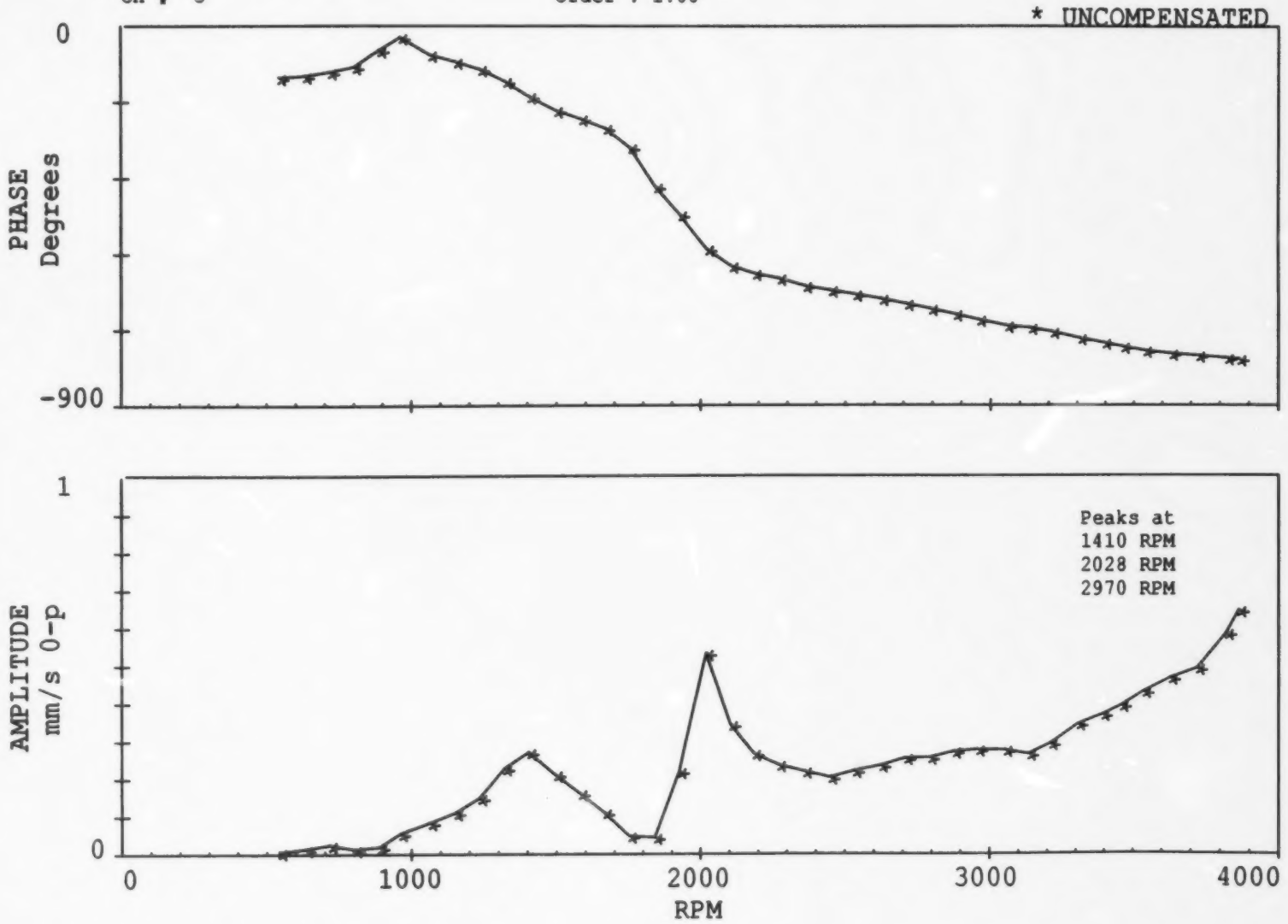


FIGURE 146
88-241

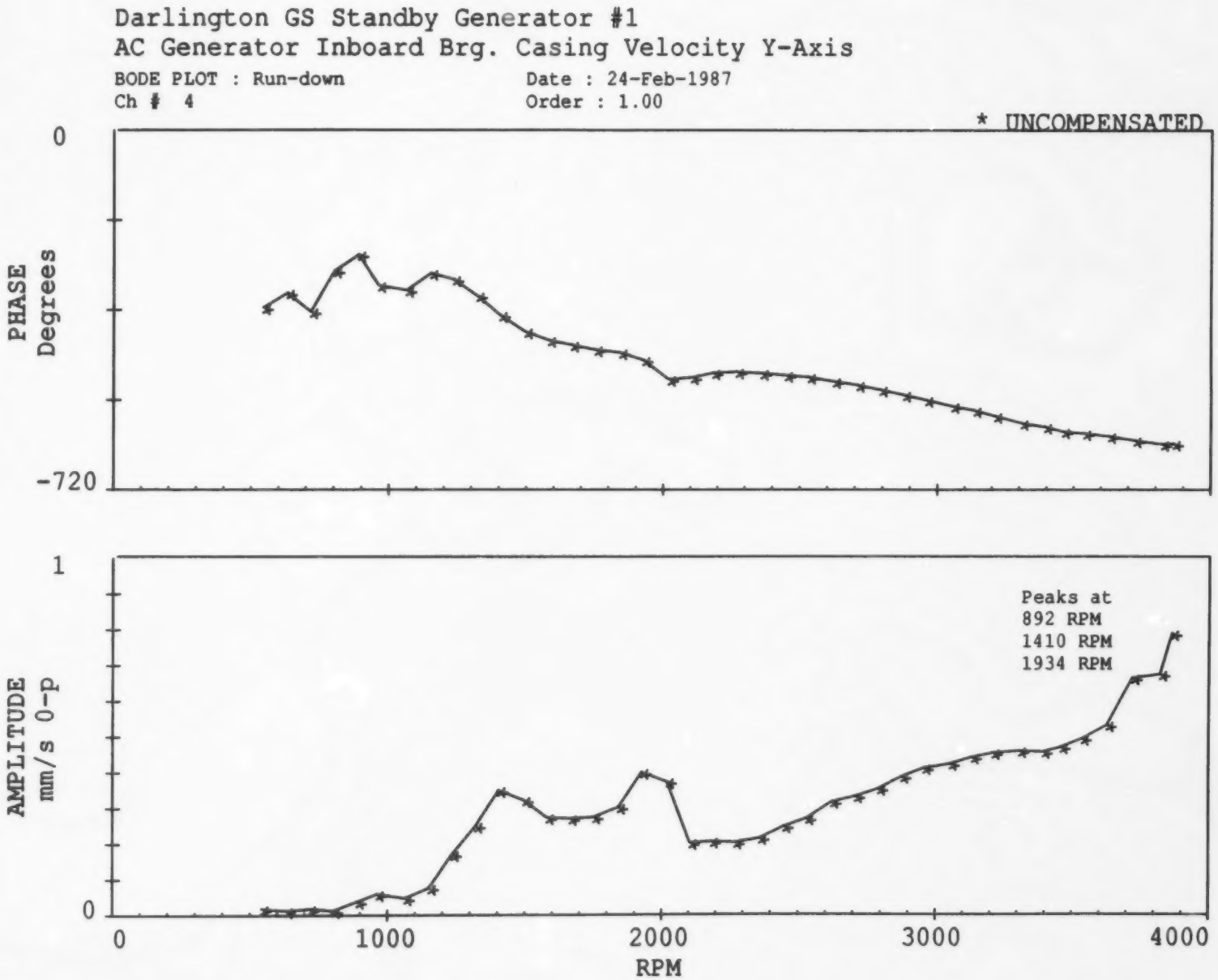


FIGURE 147
88-241

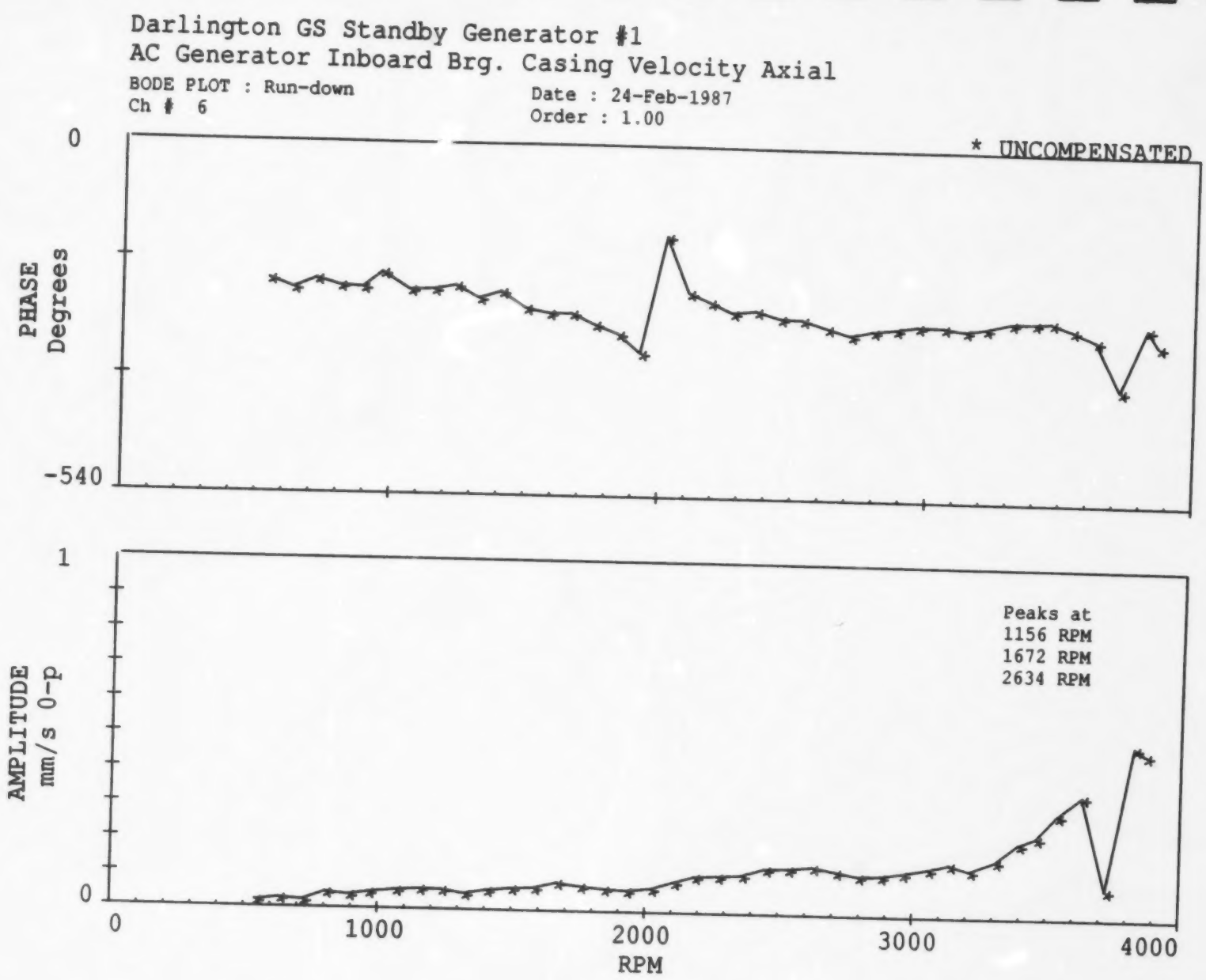


FIGURE 148
88-241

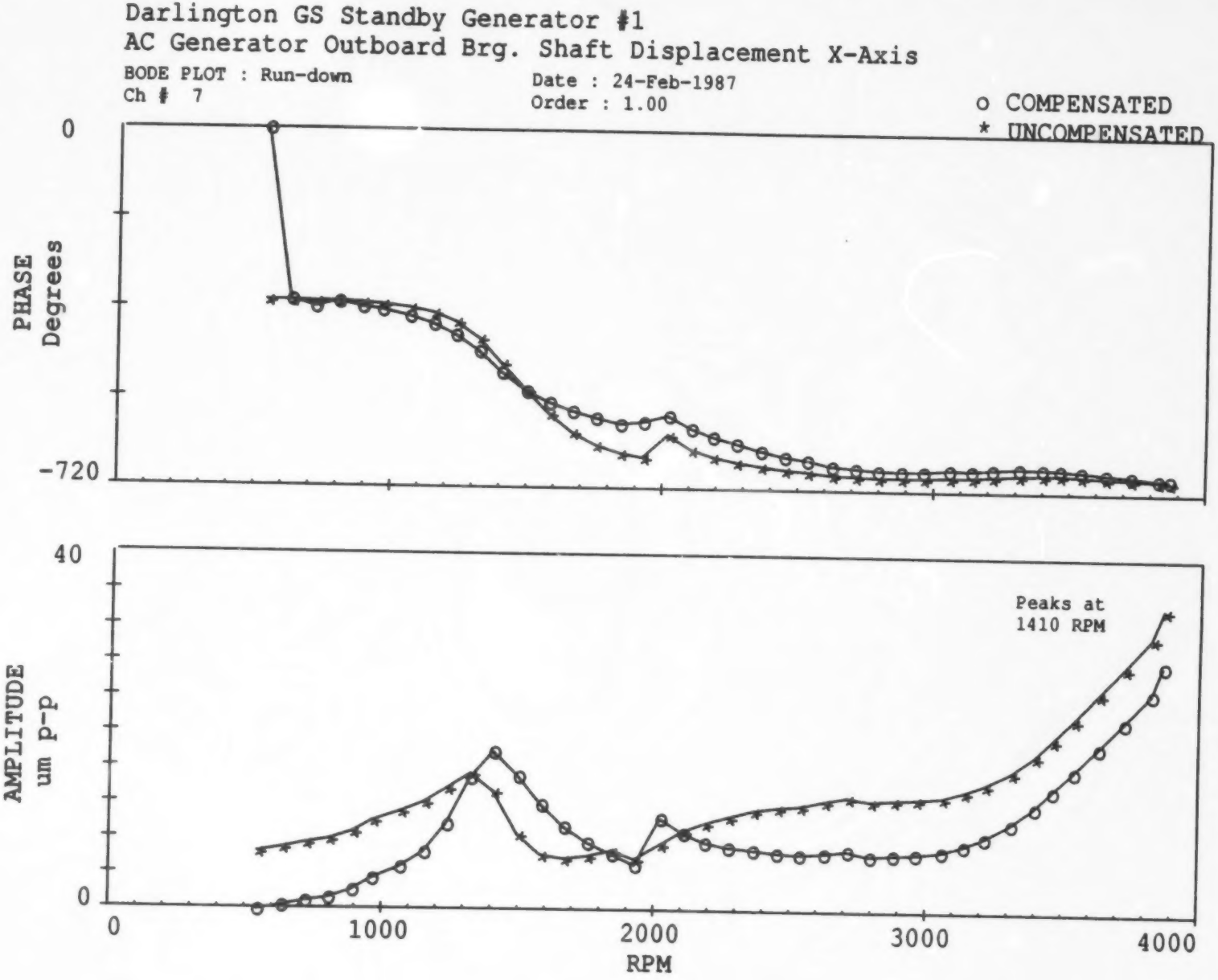


FIGURE 149
88-241

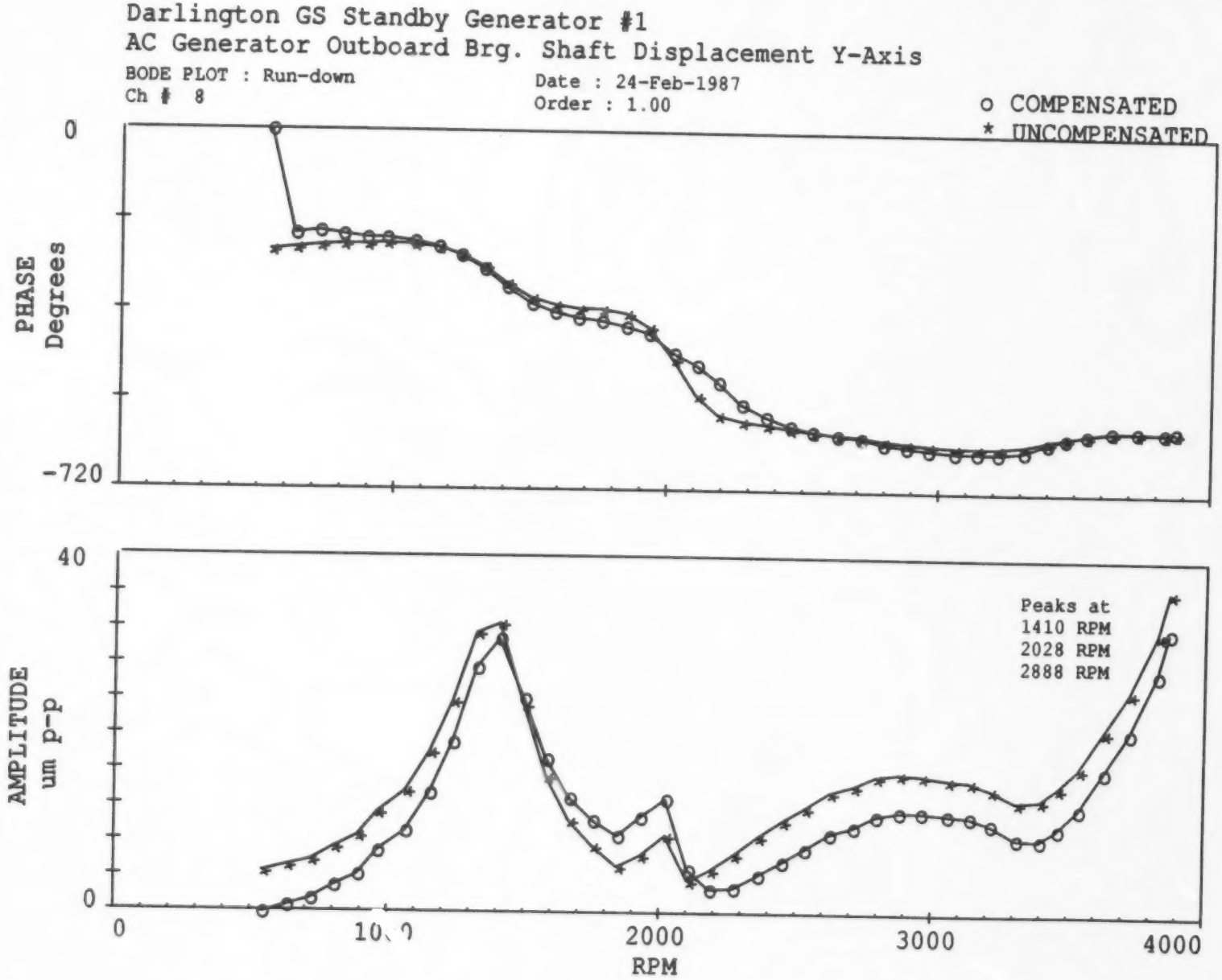


FIGURE 150
88-241

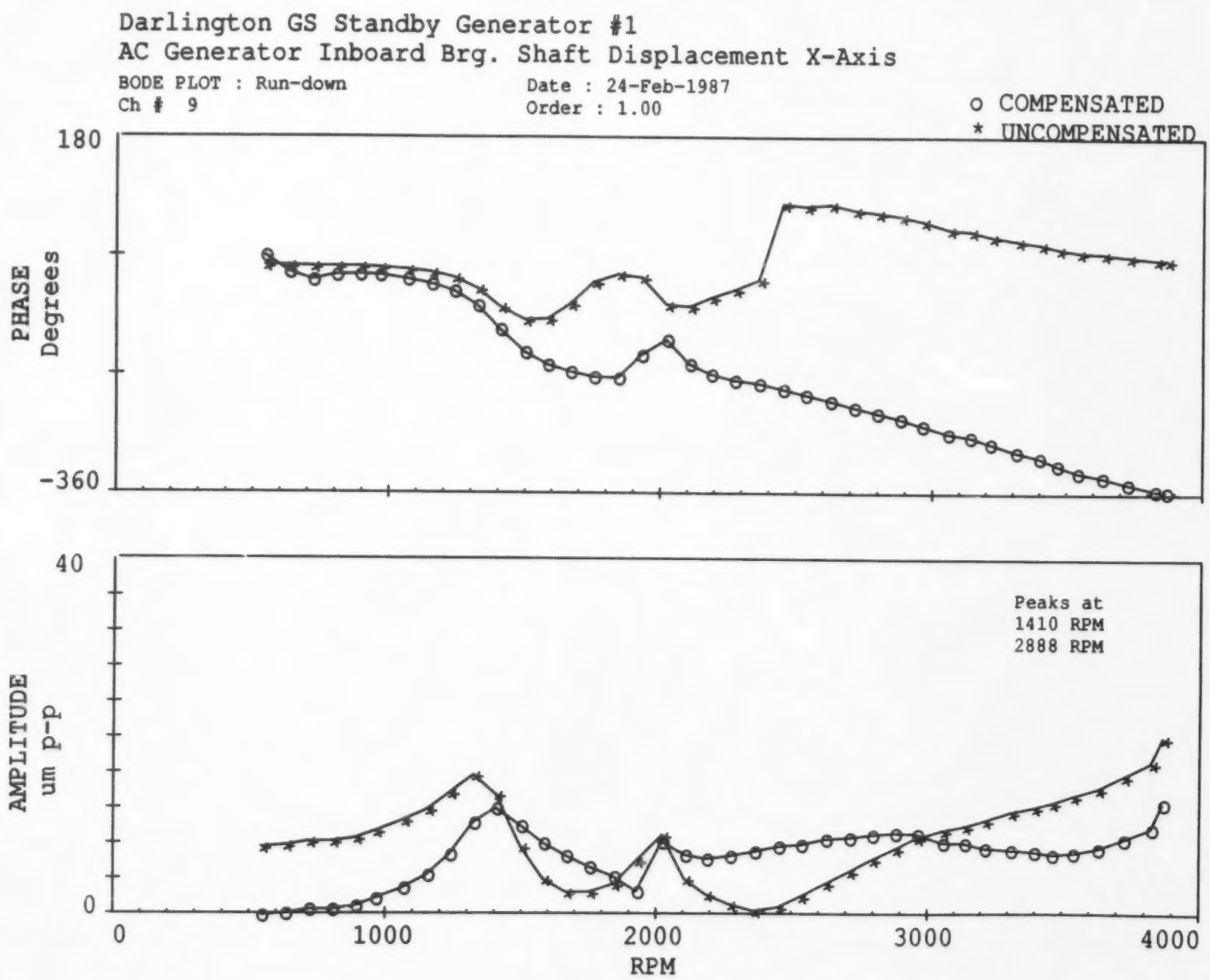


FIGURE 151
88-241

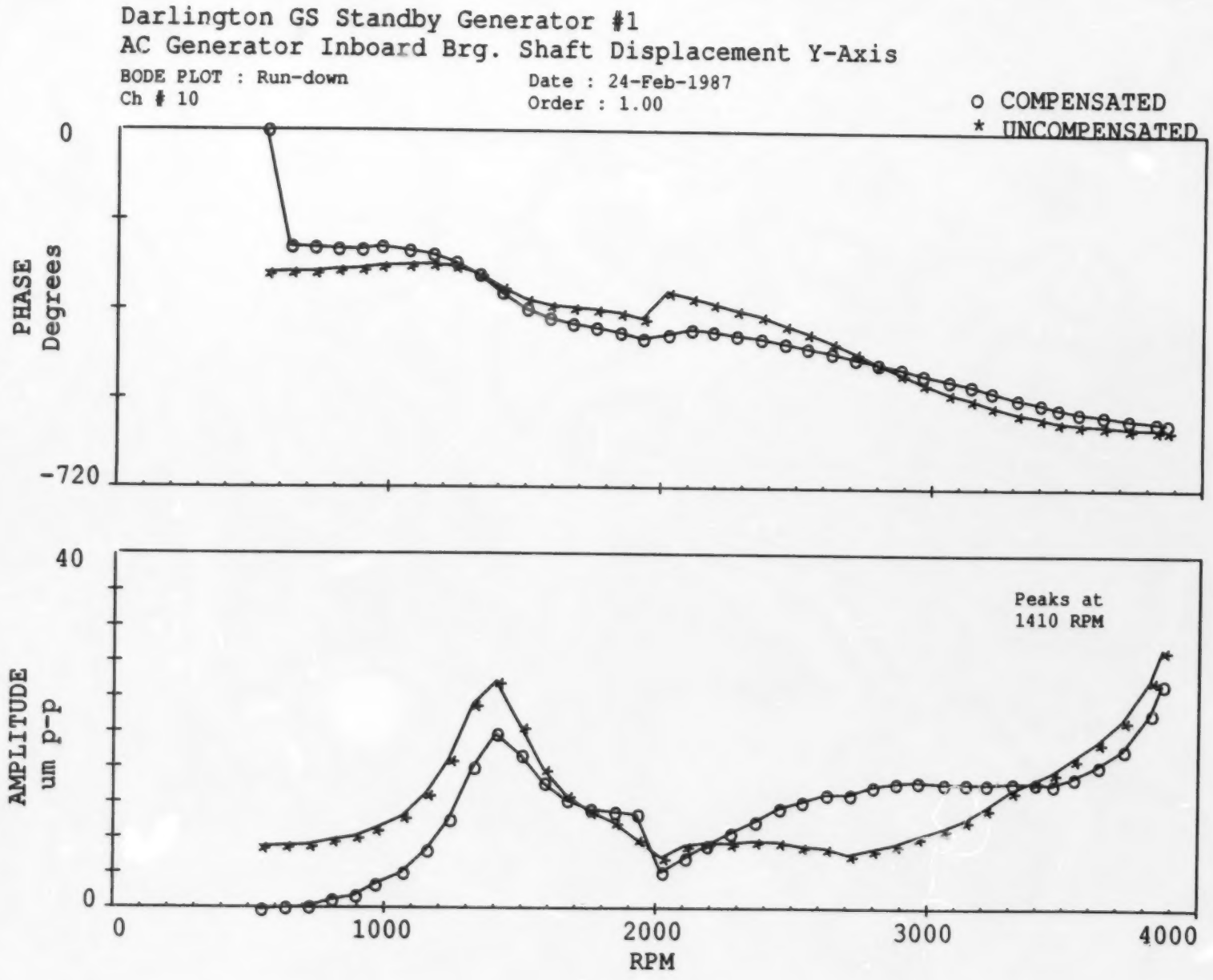


FIGURE 152
88-241

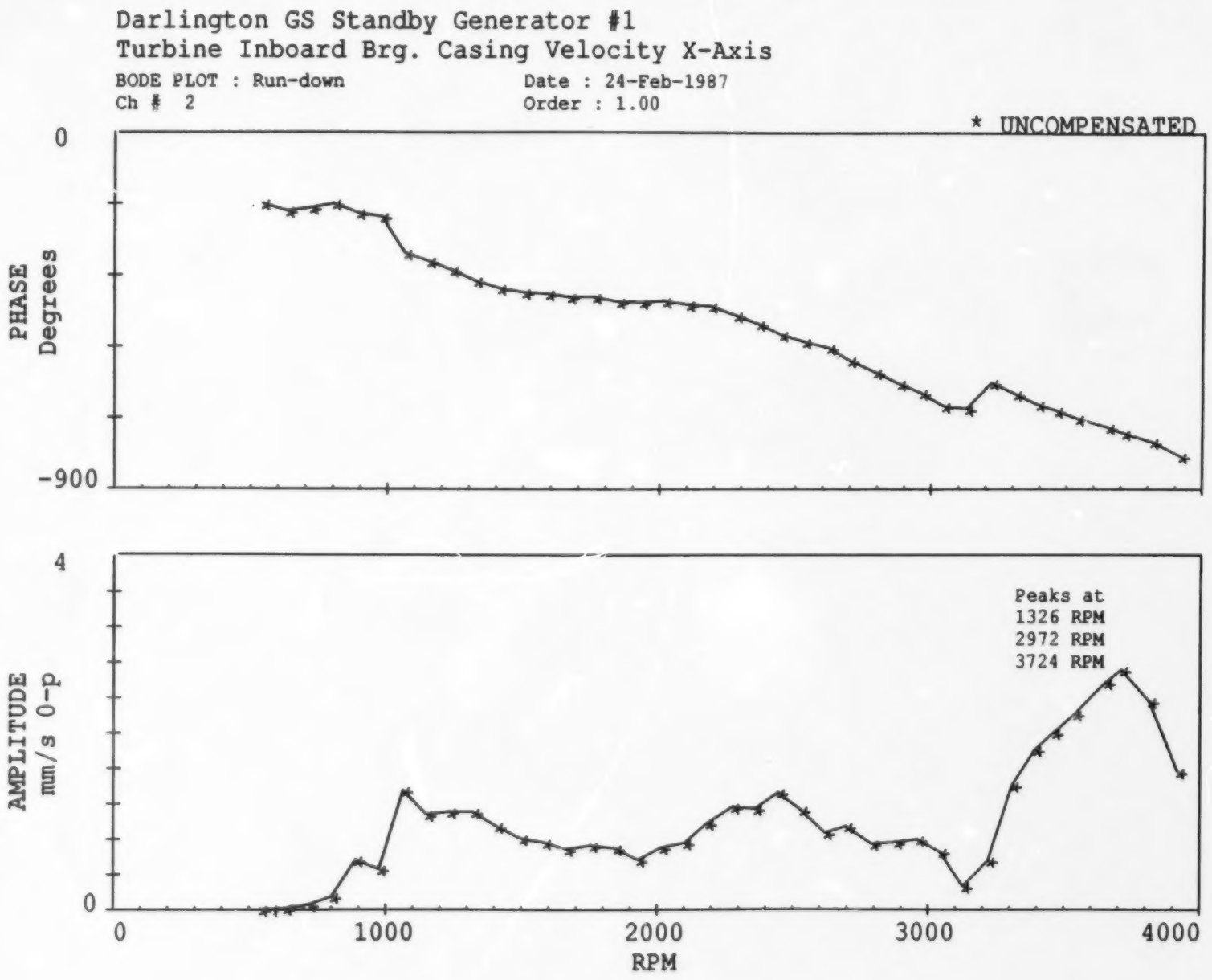


FIGURE 153
88-241

Darlington GS Standby Generator #1
Turbine Inboard Brg. Casing Velocity Y-Axis

BODE PLOT : Run-down
Ch # 1

Date : 24-Feb-1987
Order : 1.00

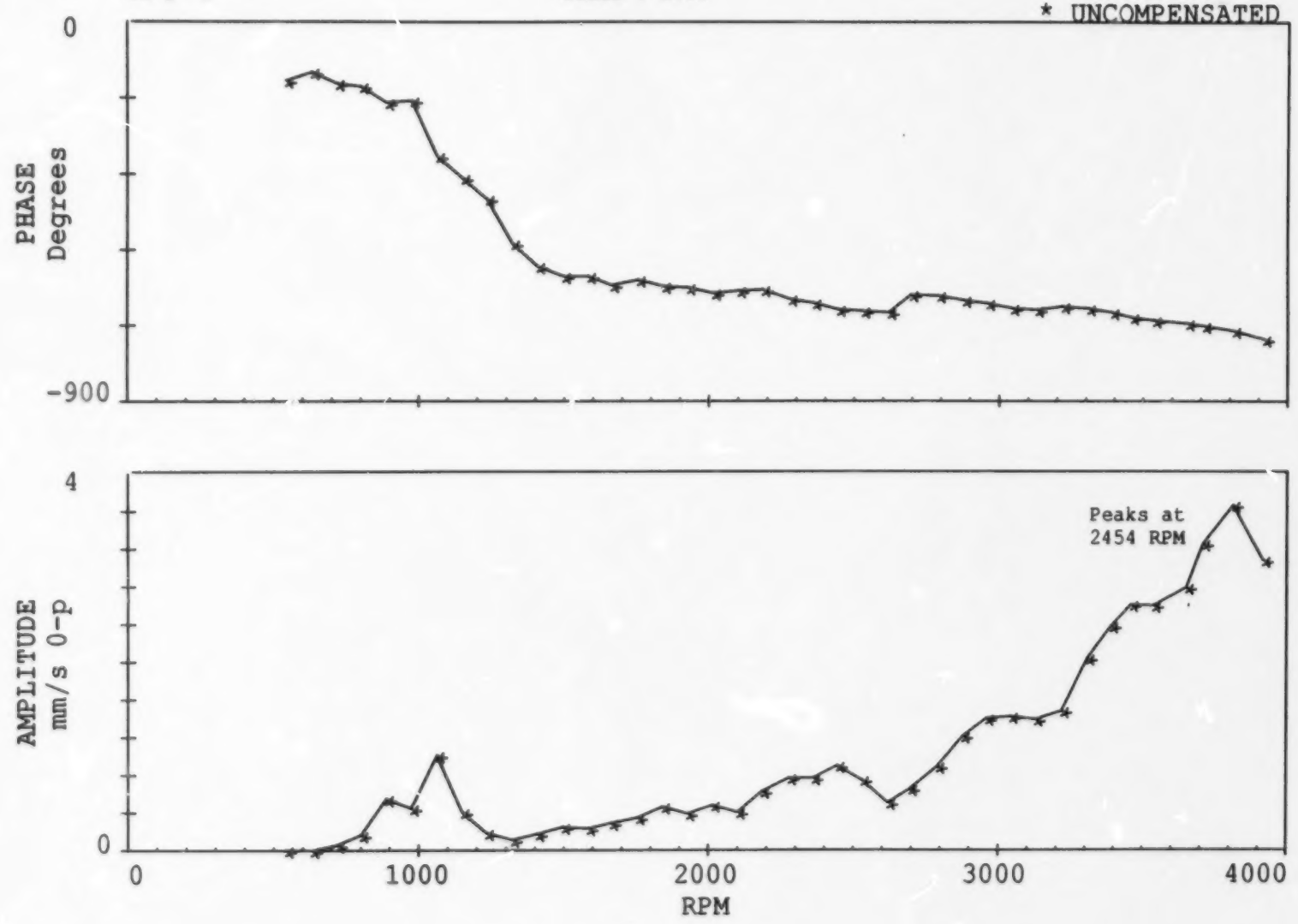


FIGURE 154

88-241

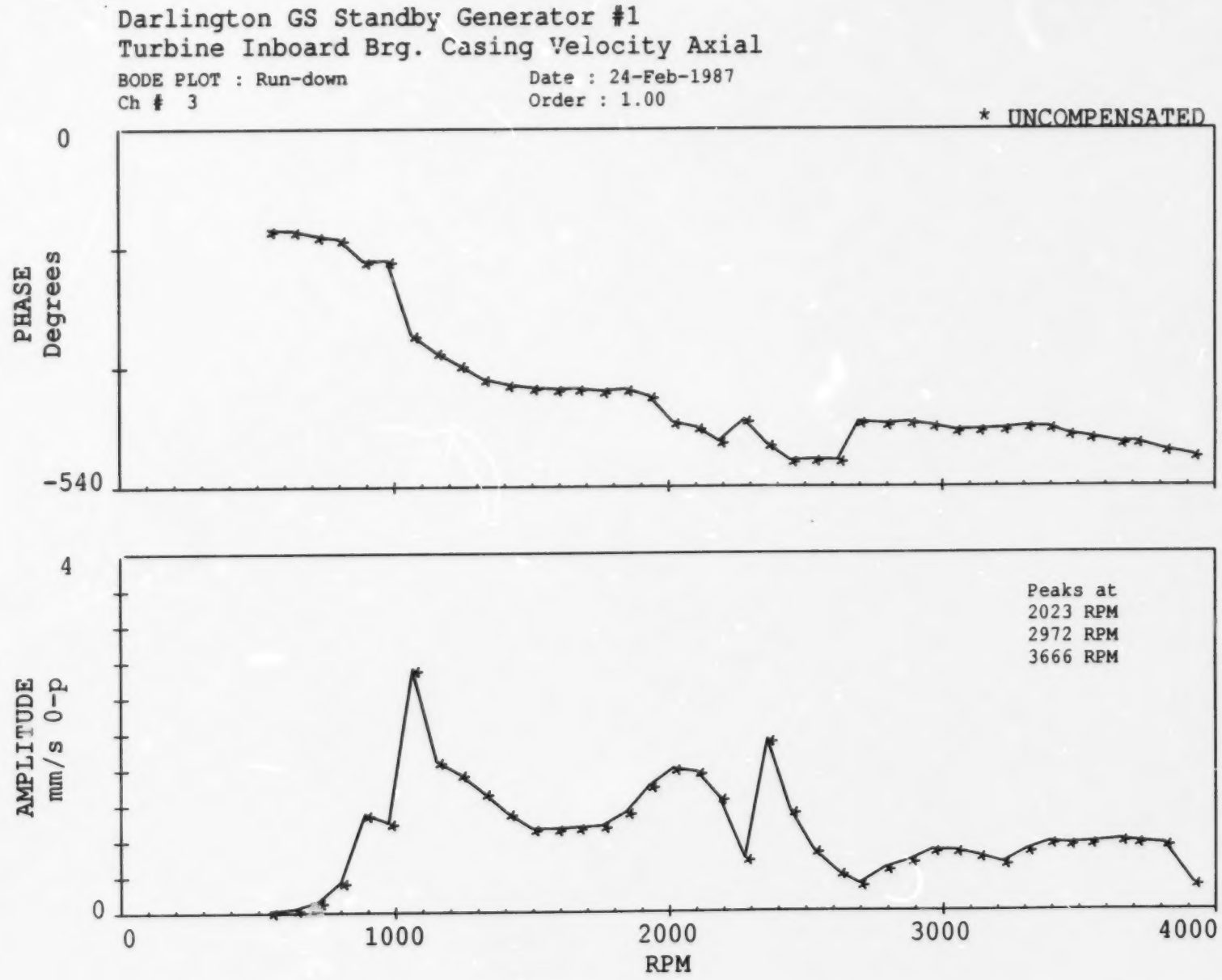


FIGURE 155
88-241

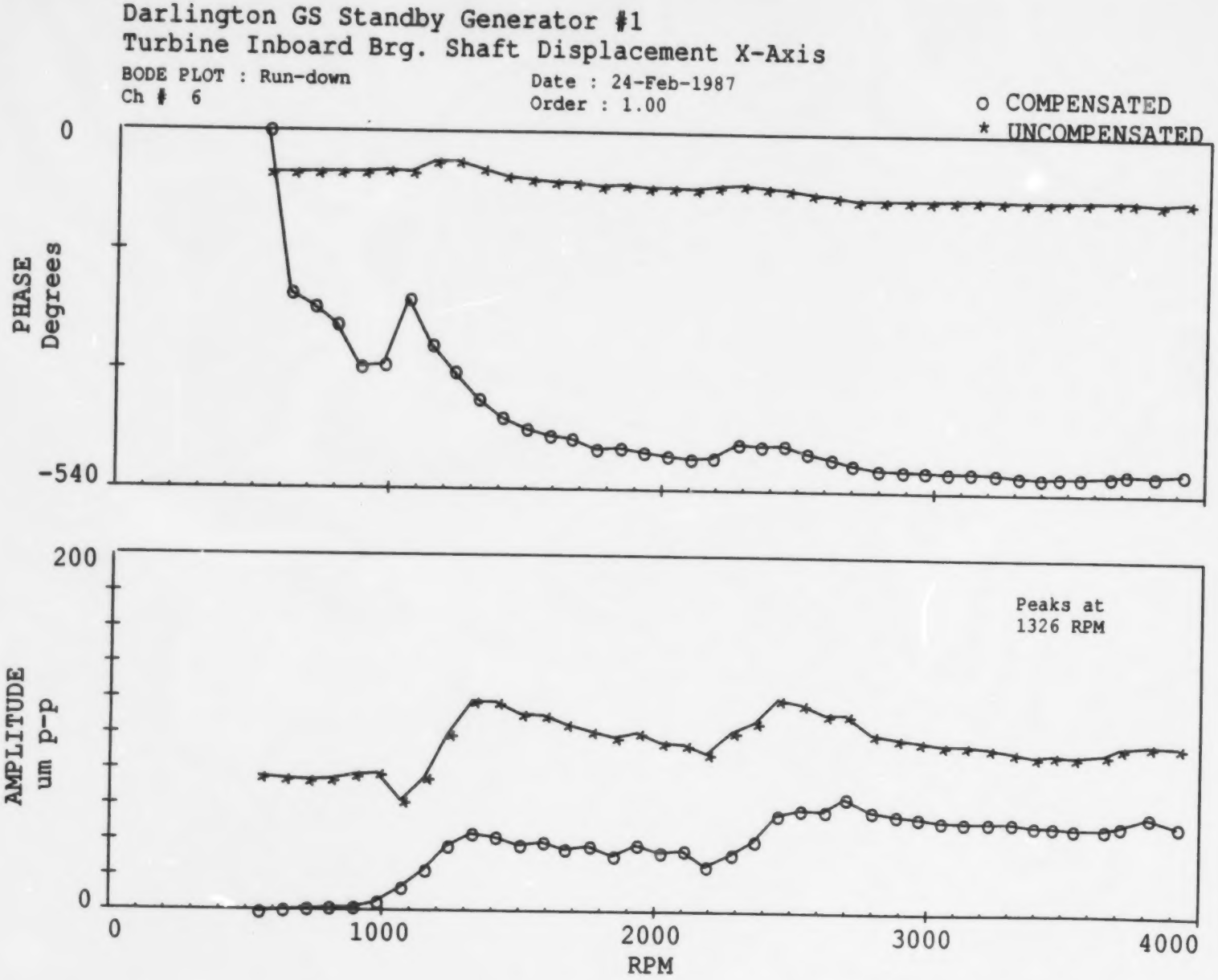


FIGURE 156
88-241

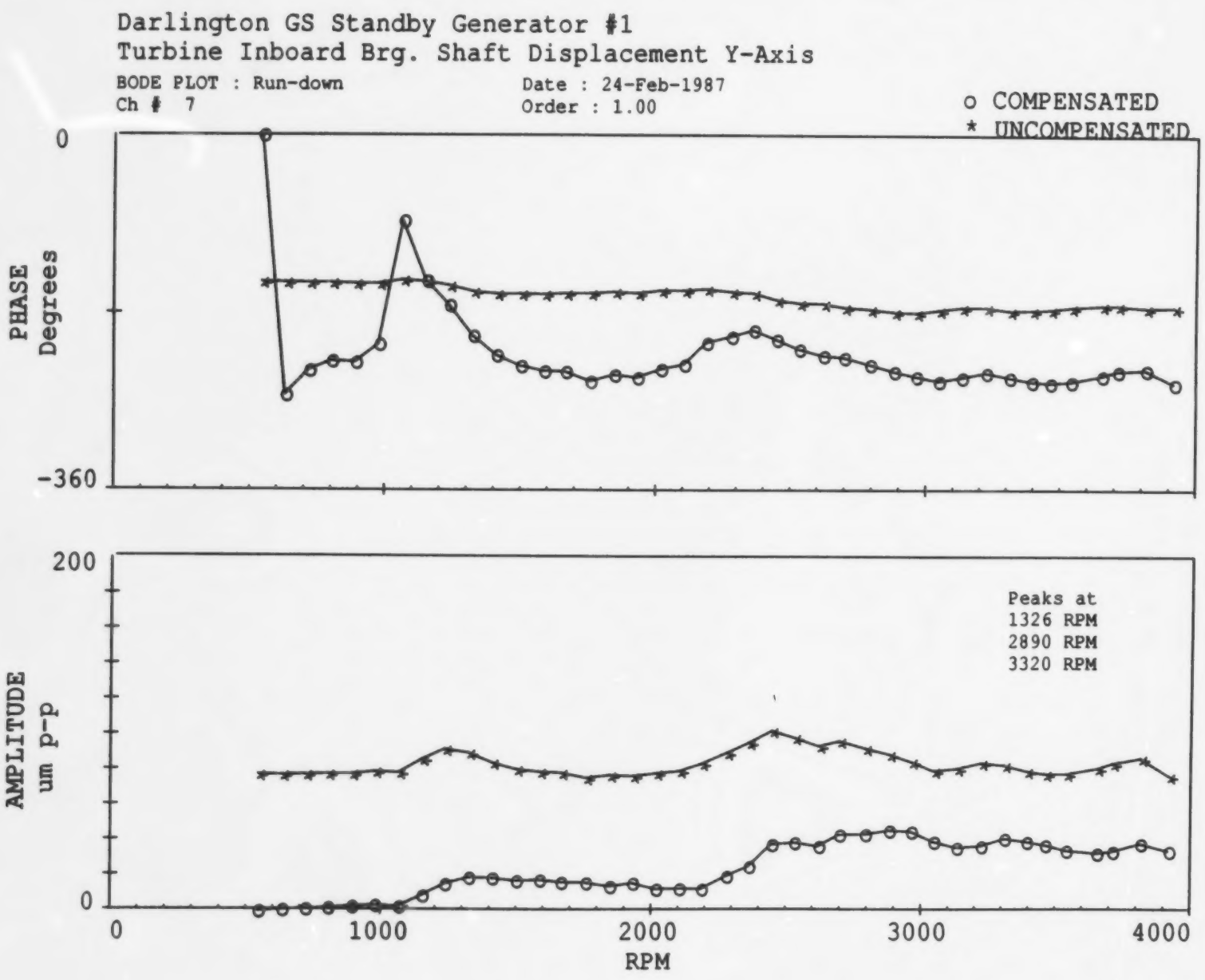


FIGURE 157

88-241

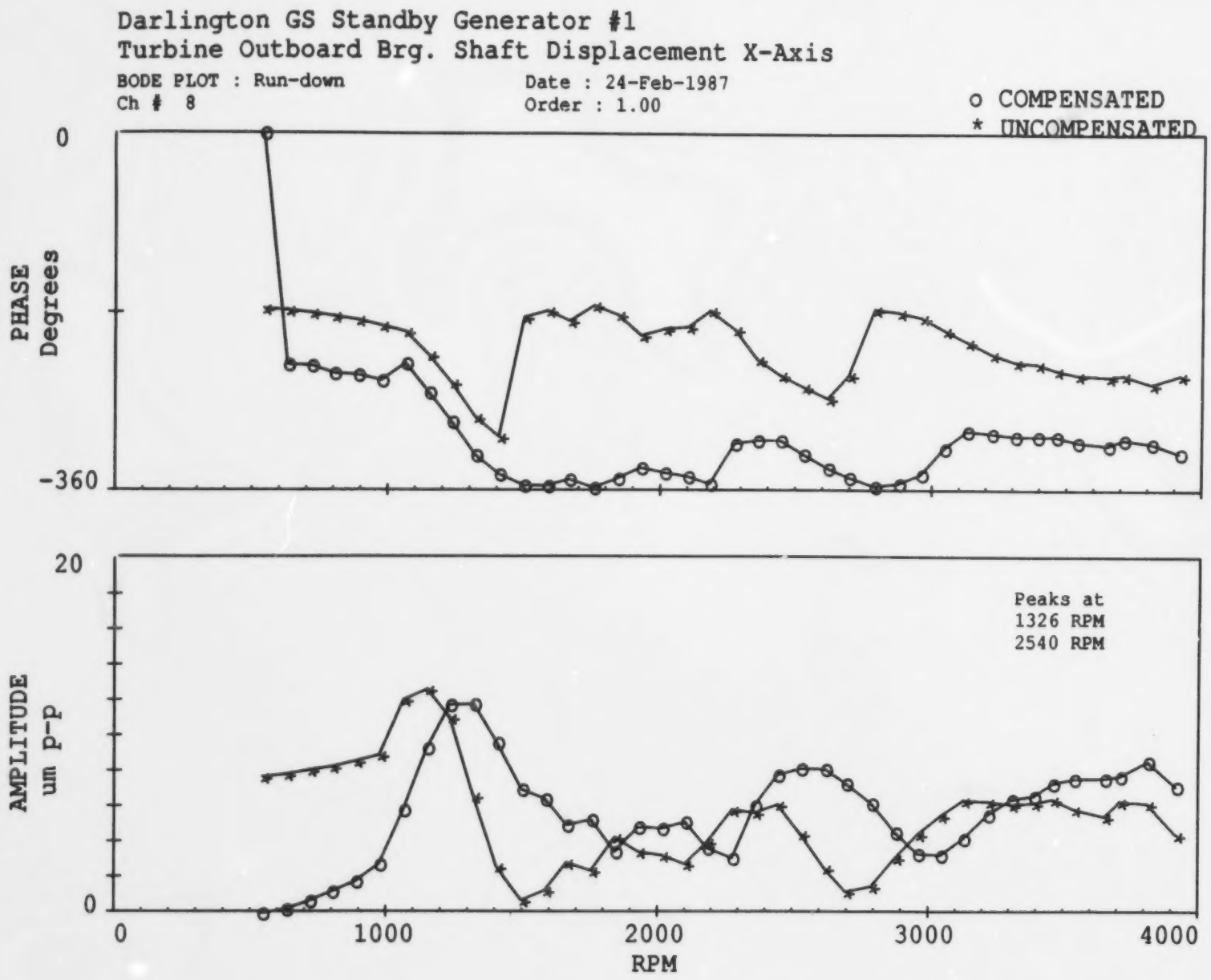


FIGURE 158
88-241

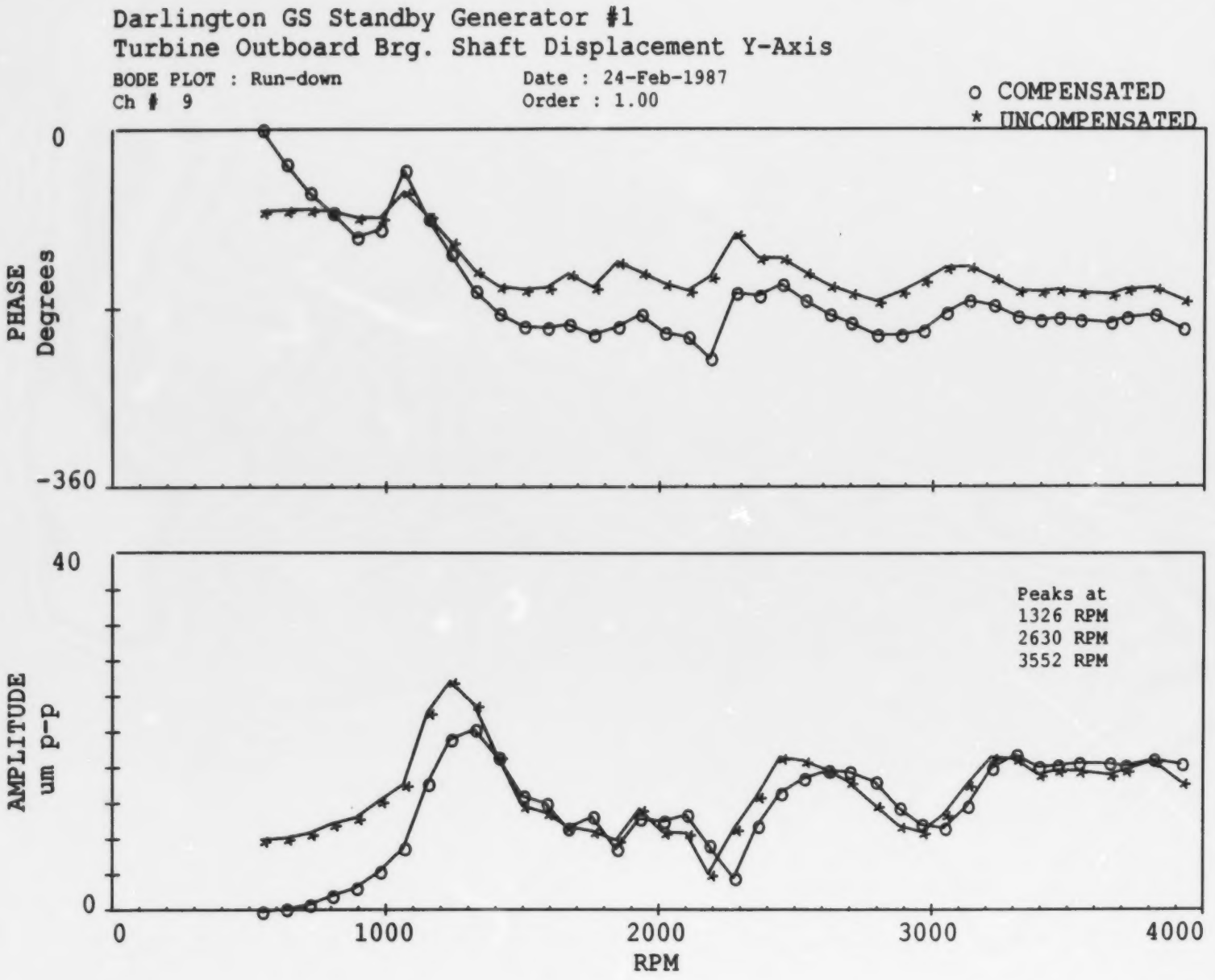


FIGURE 159
88-241

Darlington GS Standby Generator #1
AC Generator

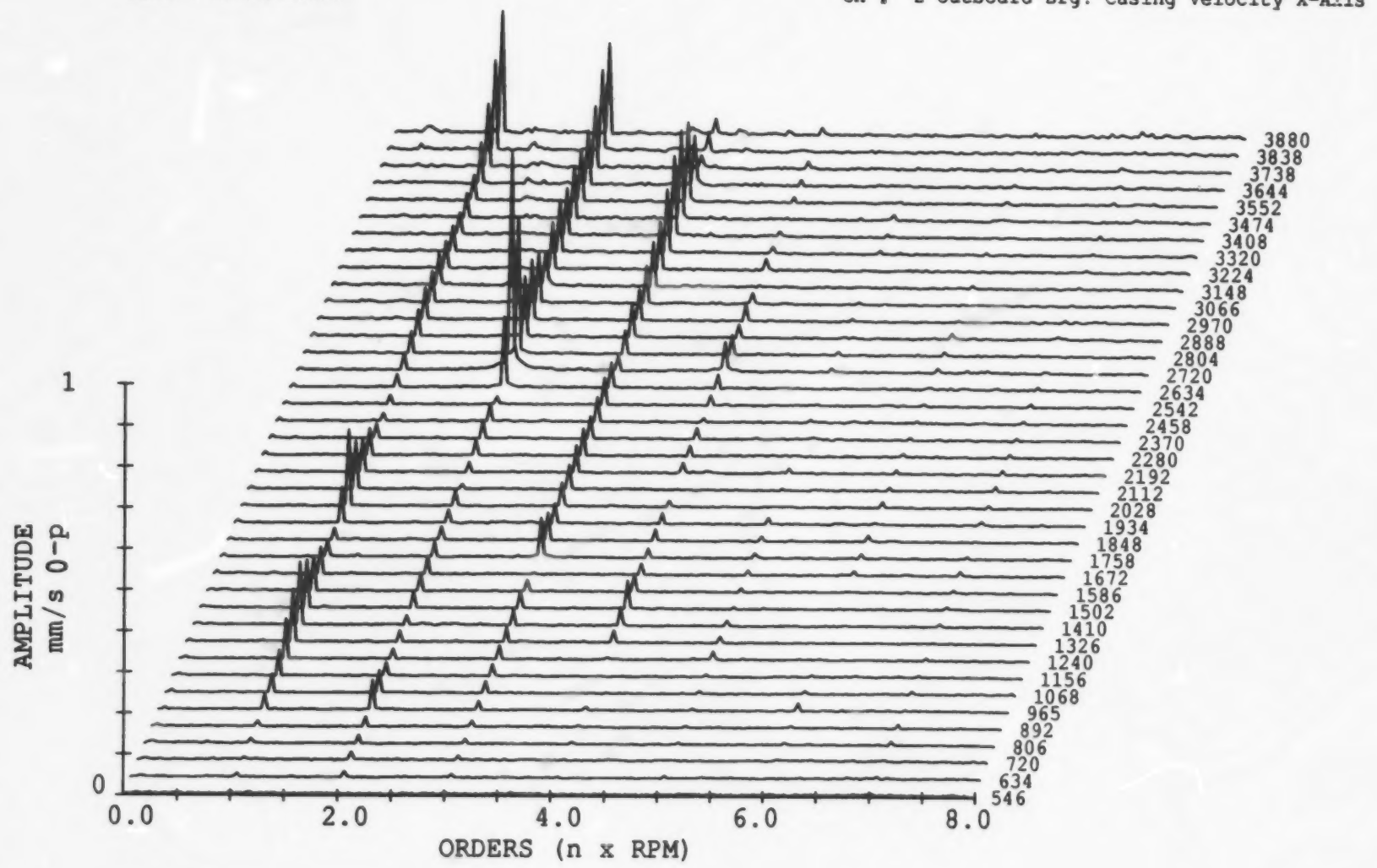


FIGURE 160
88-241

Darlington GS Standby Generator #1
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 24-Feb-1987

Ch # 1 Outboard Brg. Casing Velocity Y-Axis

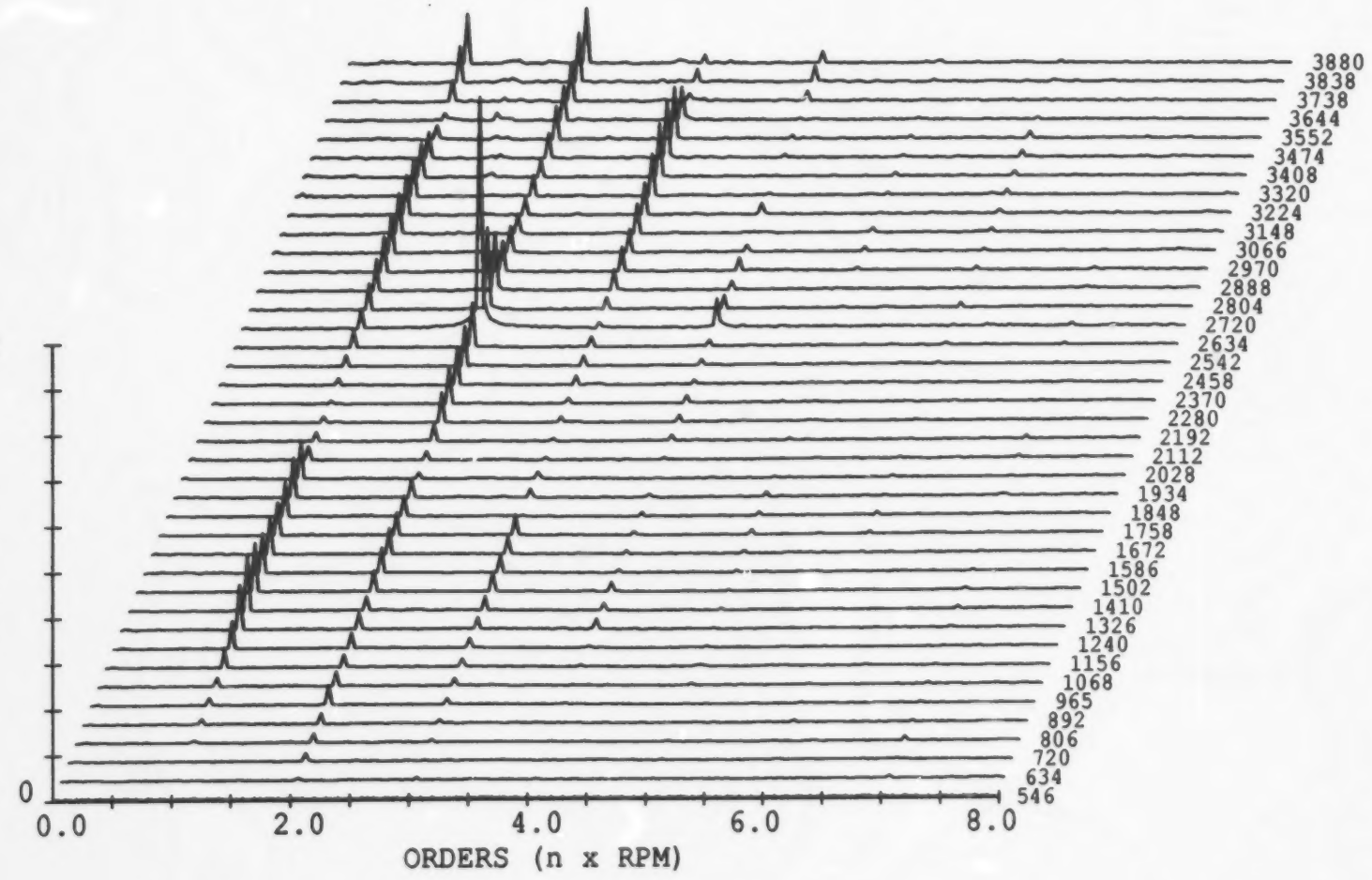


FIGURE 161
88-241

Darlington GS Standby Generator #1
AC Generator

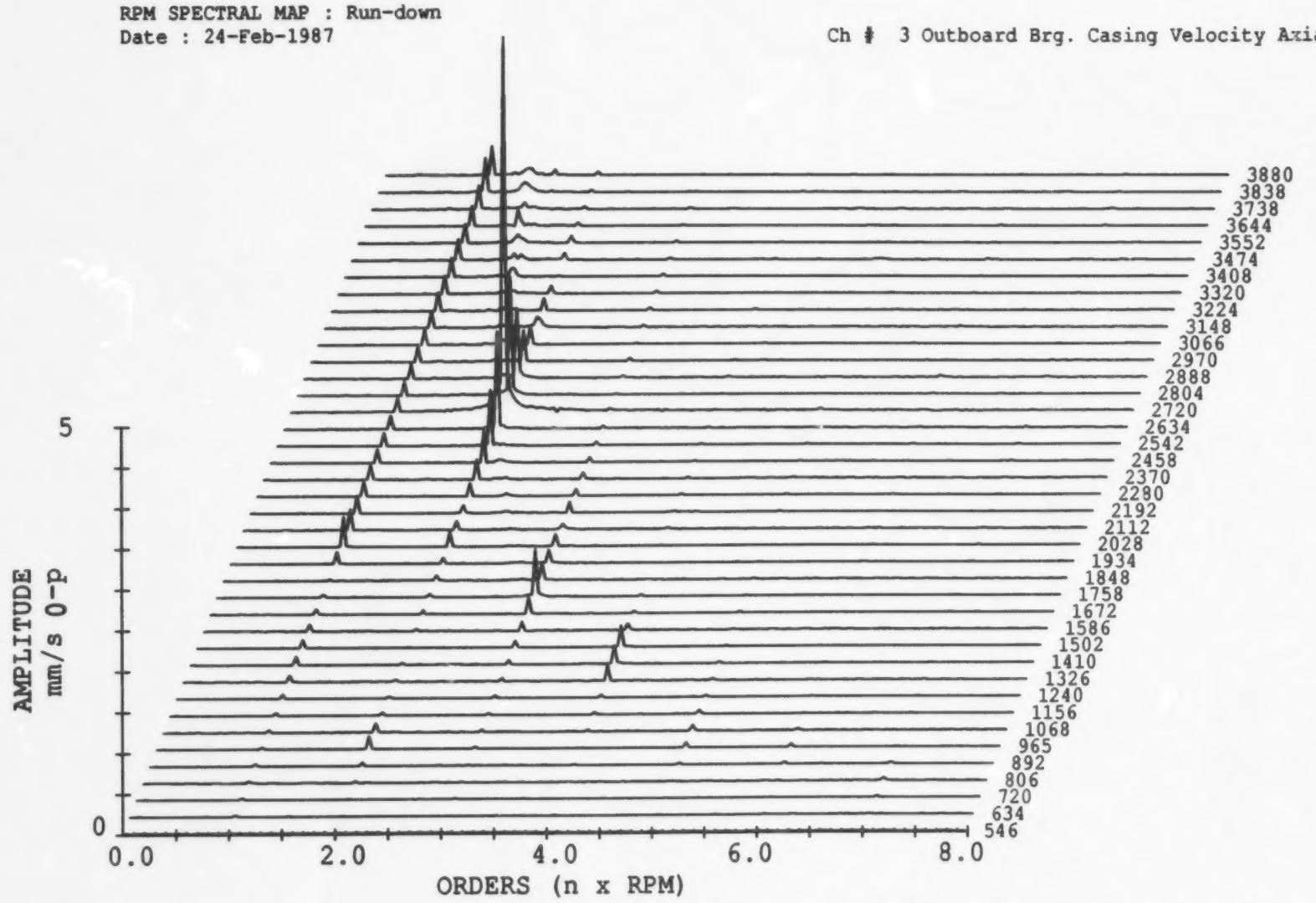


FIGURE 162
88-241

Darlington GS Standby Generator #1
AC Generator

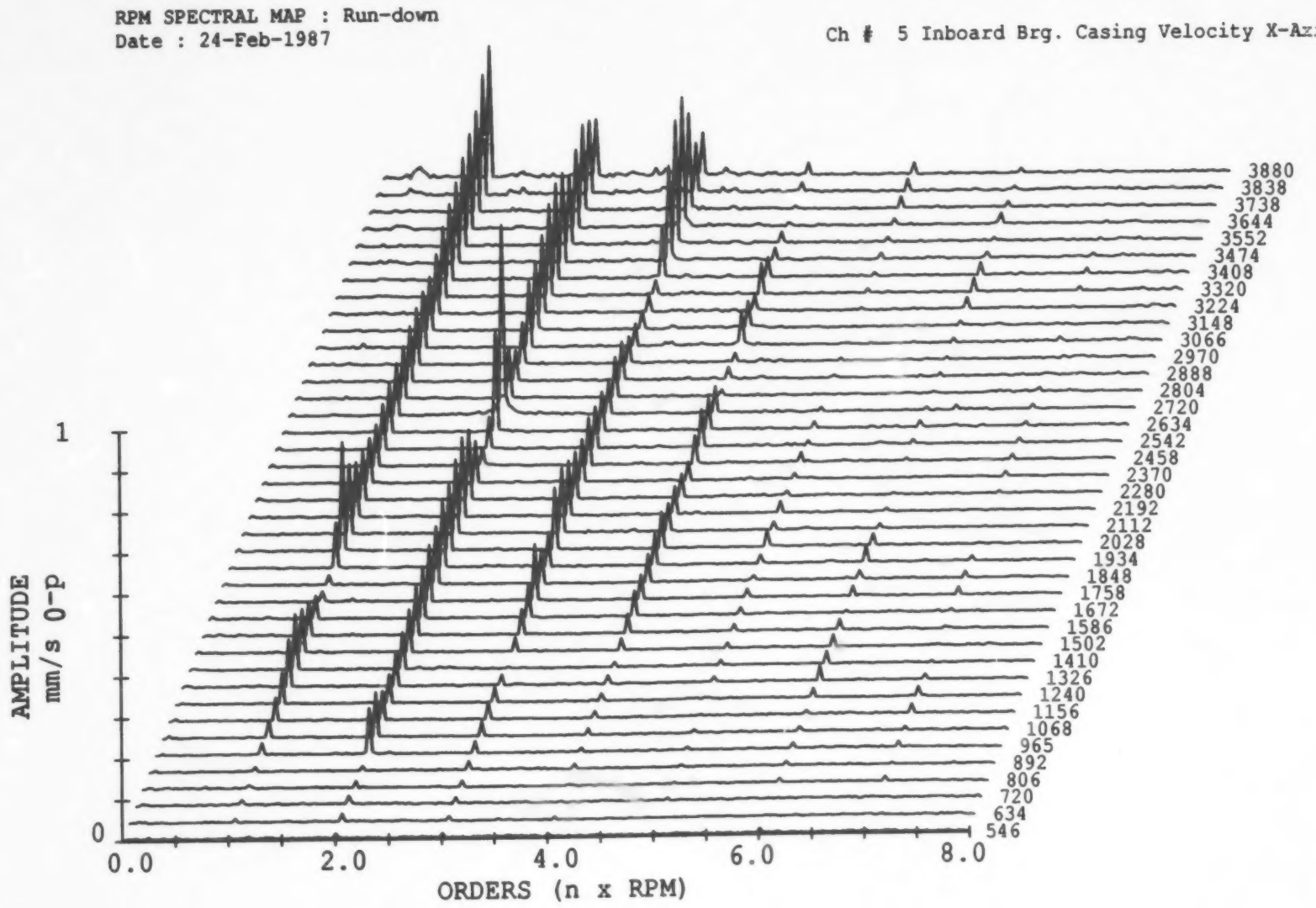


FIGURE 163
88-241

Darlington GS Standby Generator #1
AC Generator

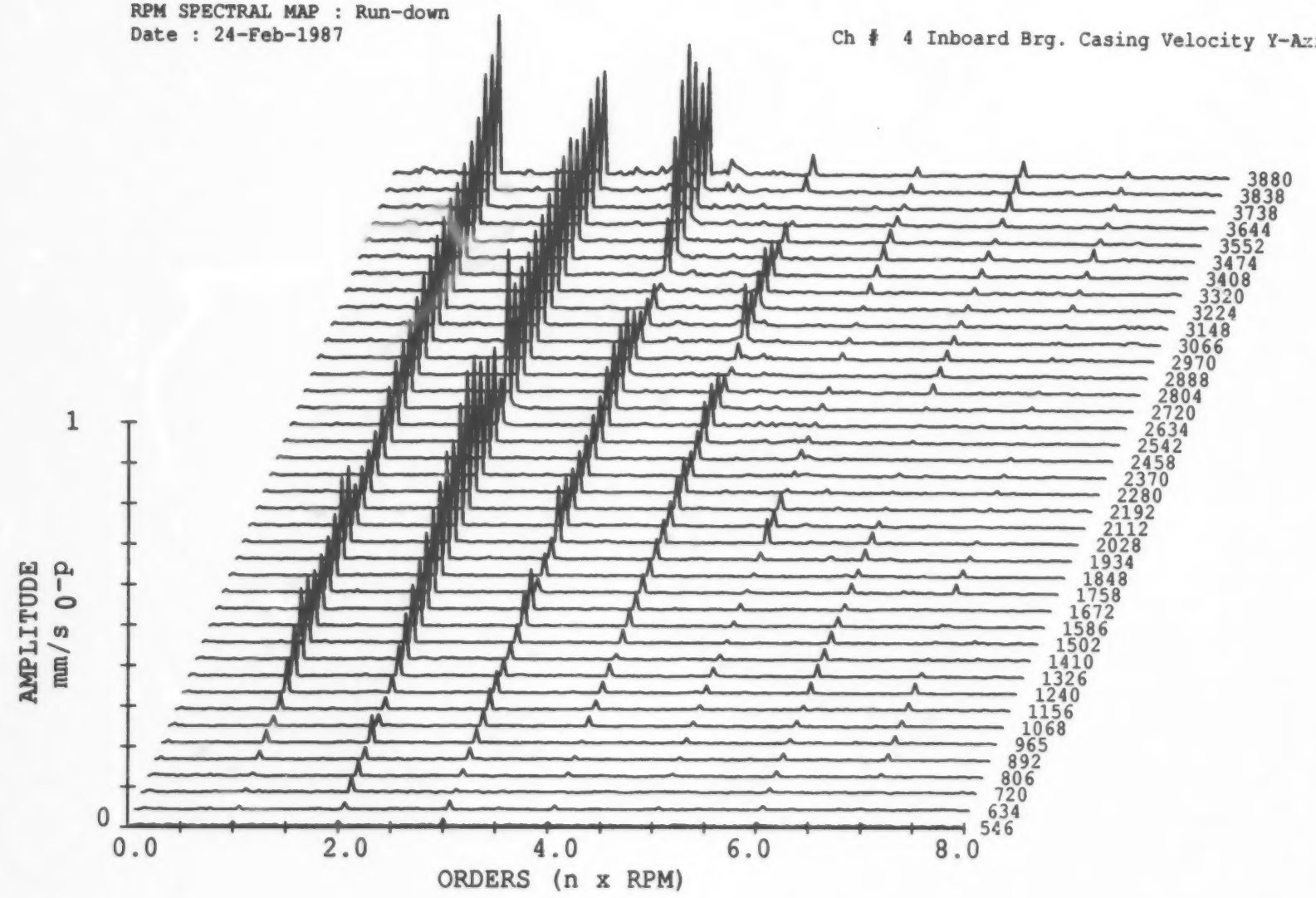


FIGURE 164
88-241

Darlington GS Standby Generator #1
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 24-Feb-1987

Ch # 6 Inboard Brg. Casing Velocity Axial

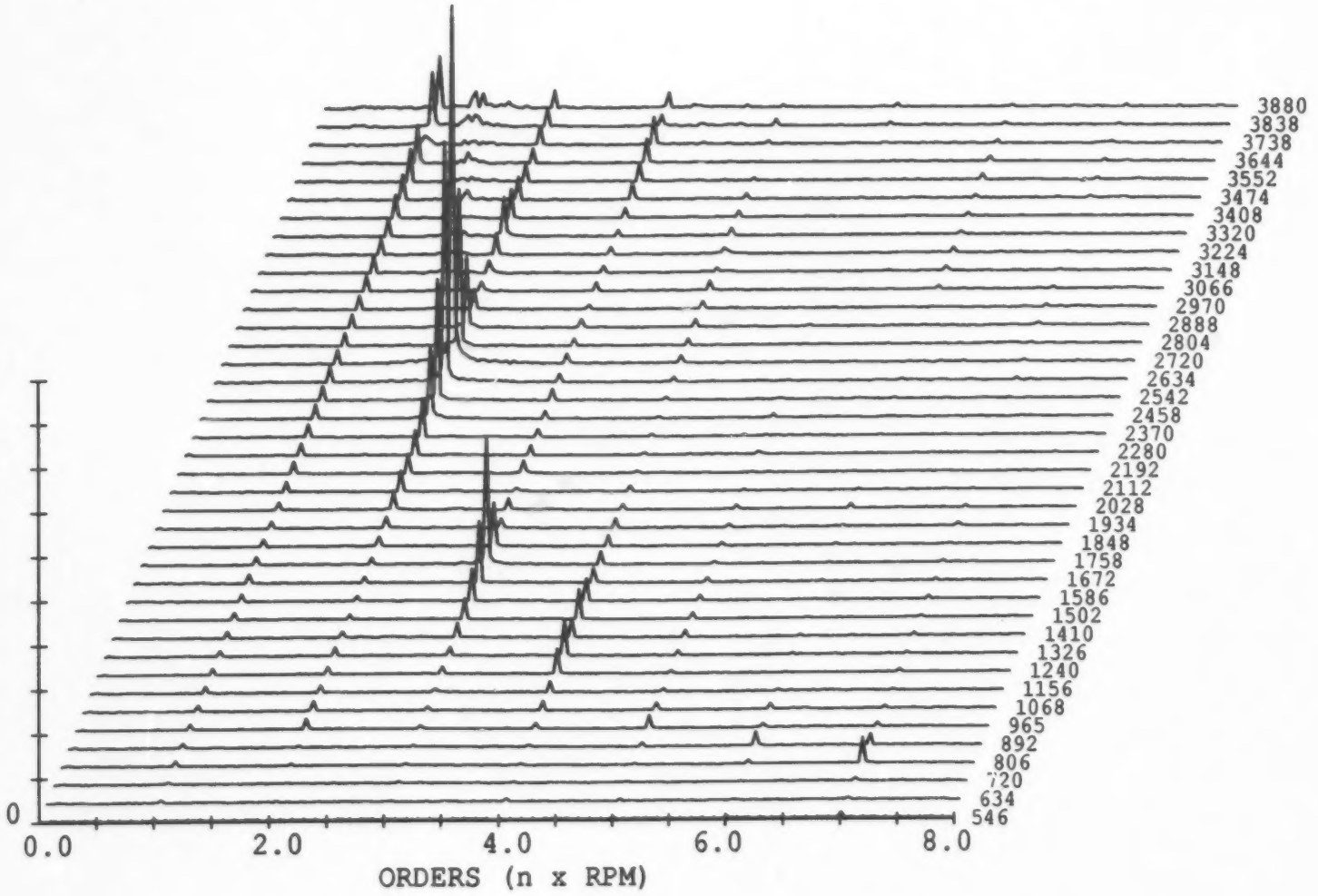


FIGURE 165

88-241

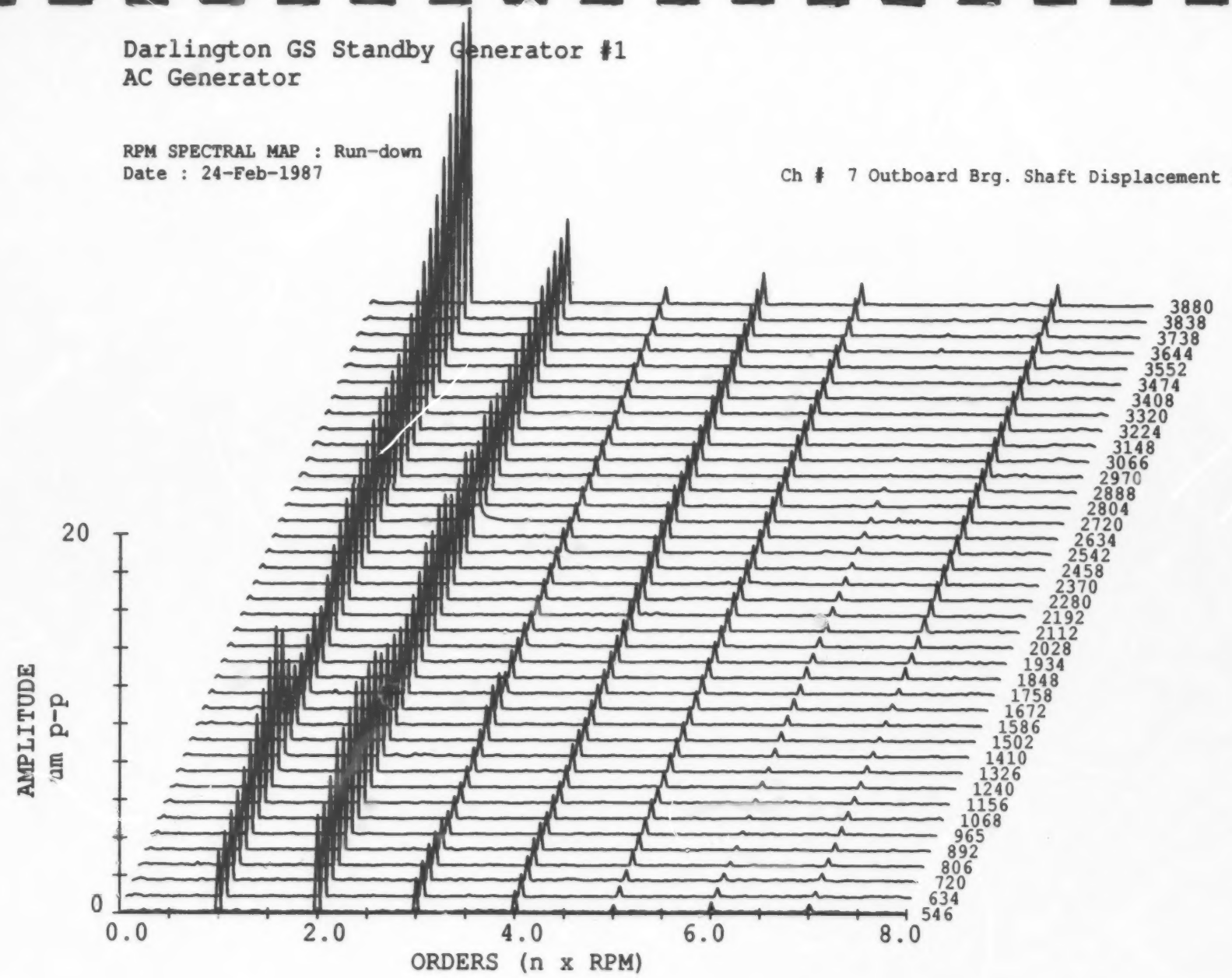


FIGURE 166
88-241

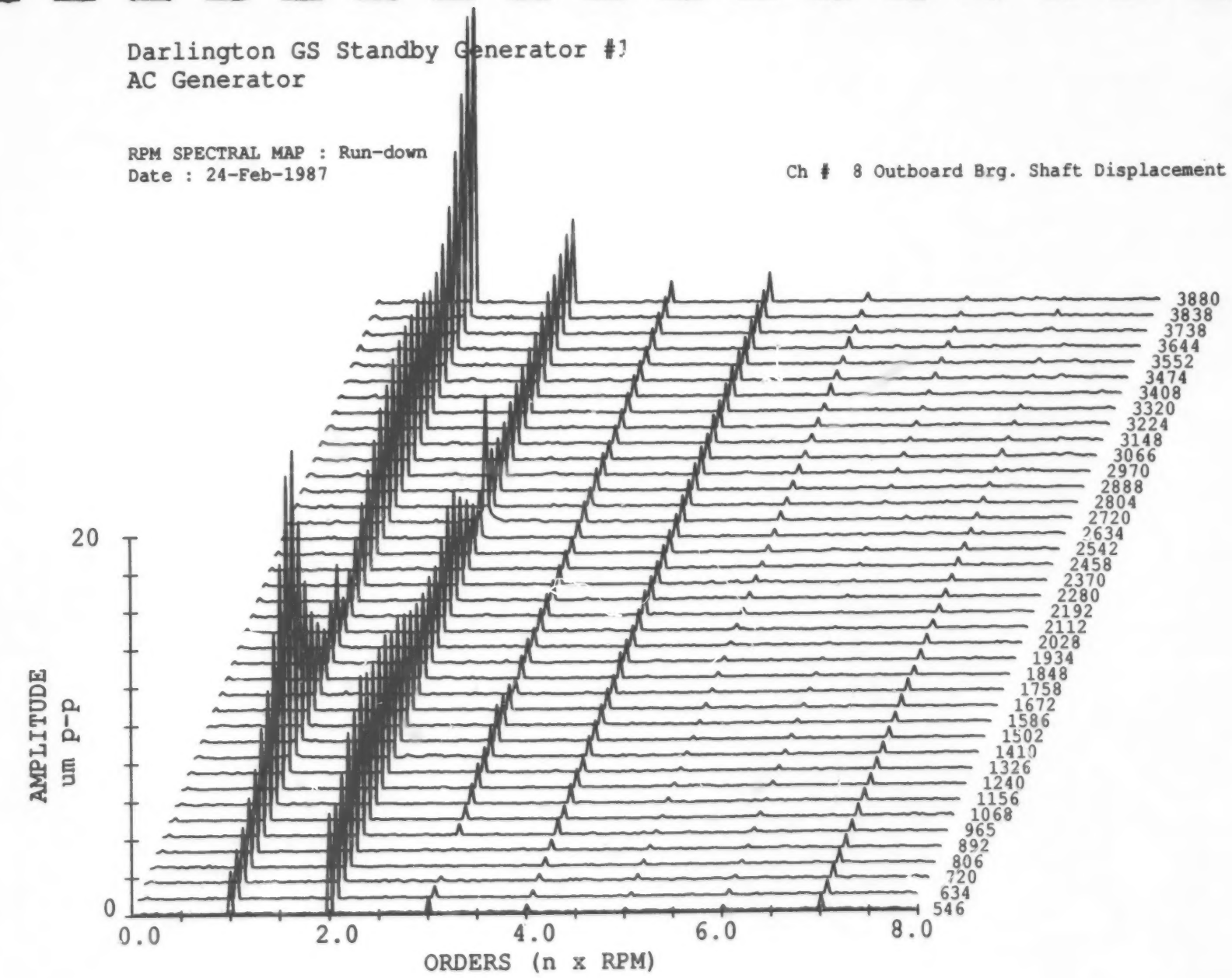


FIGURE 167
88-241

Darlington GS Standby Generator #1
AC Generator

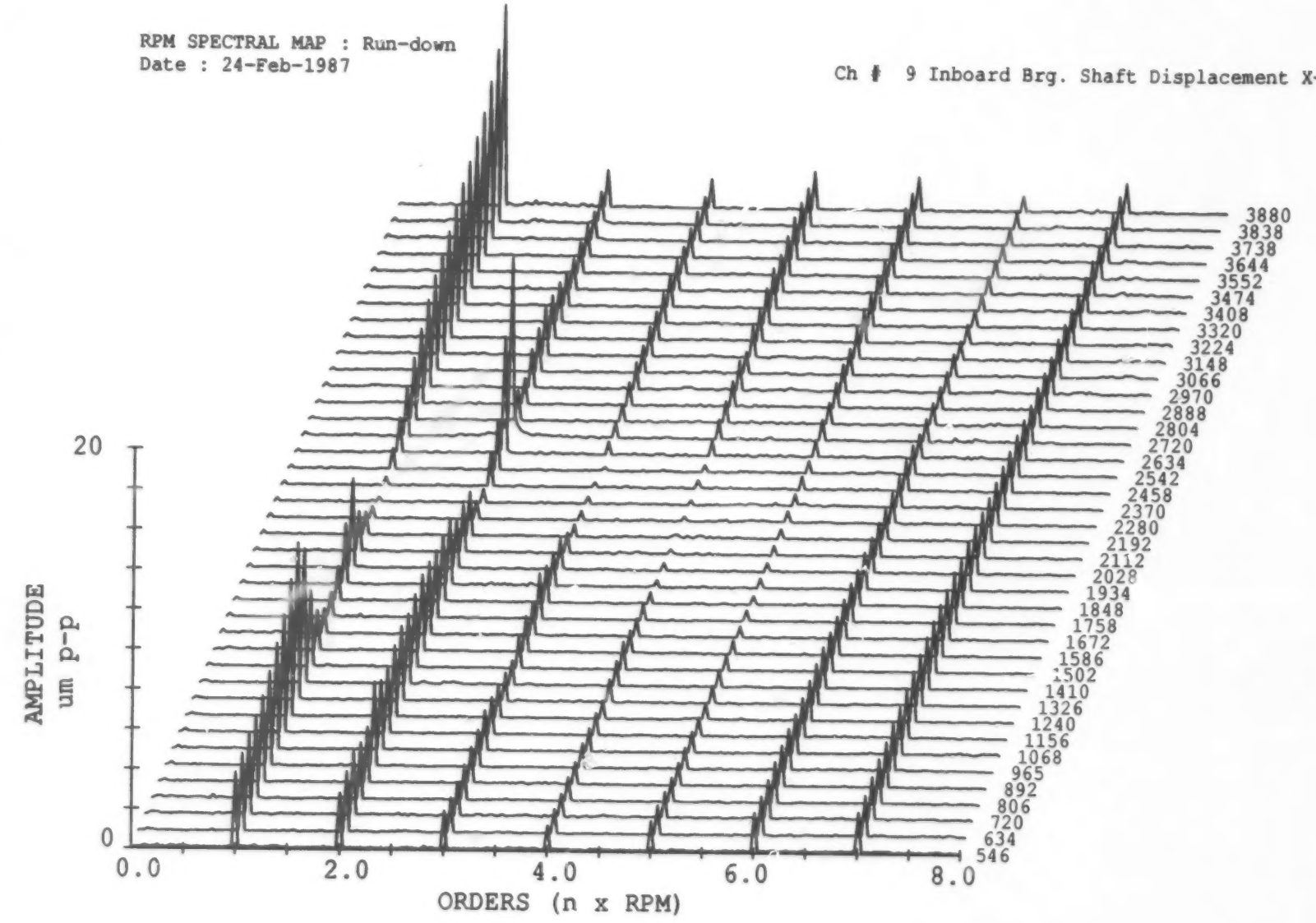


FIGURE 168
88-241

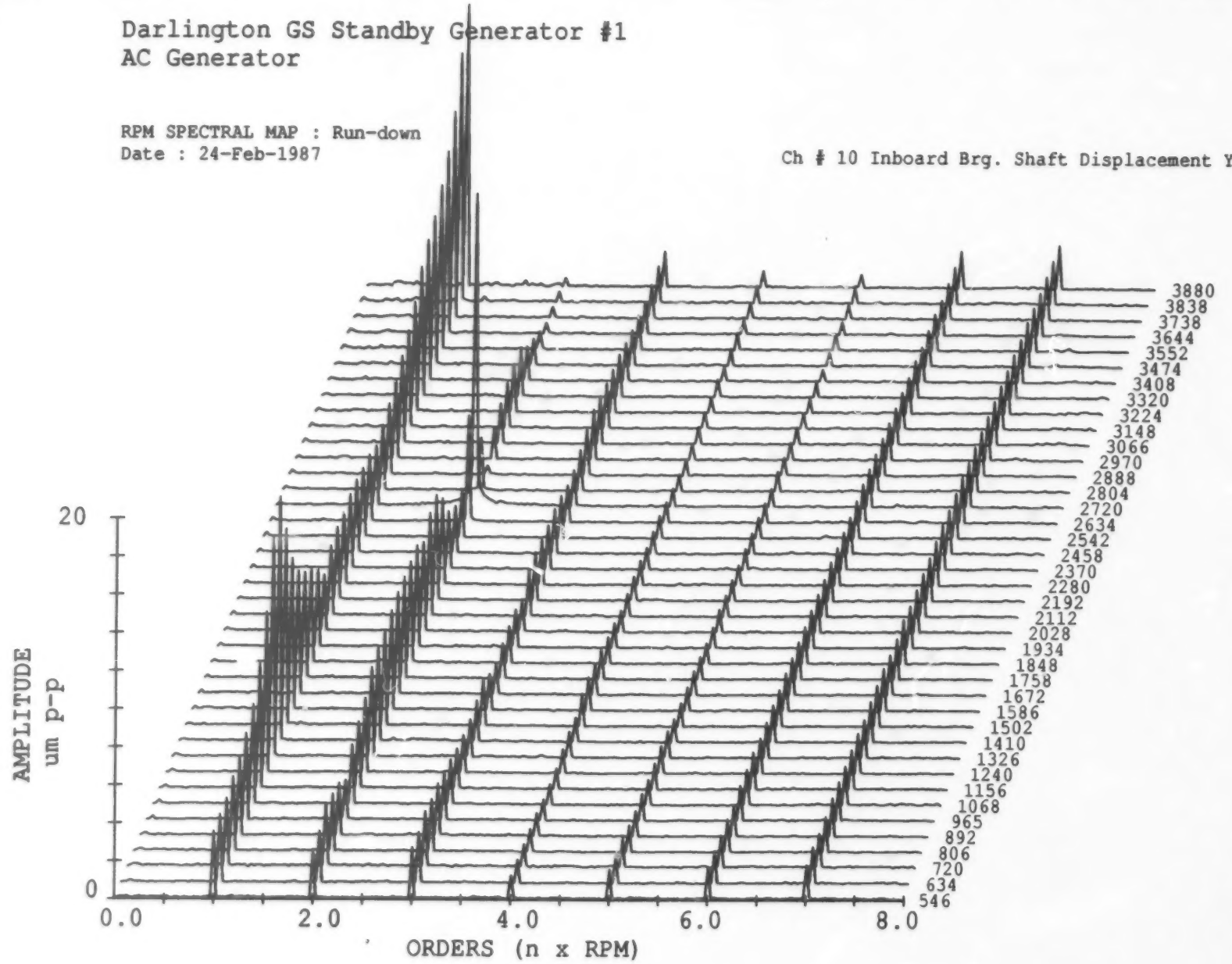


FIGURE 169

88-241

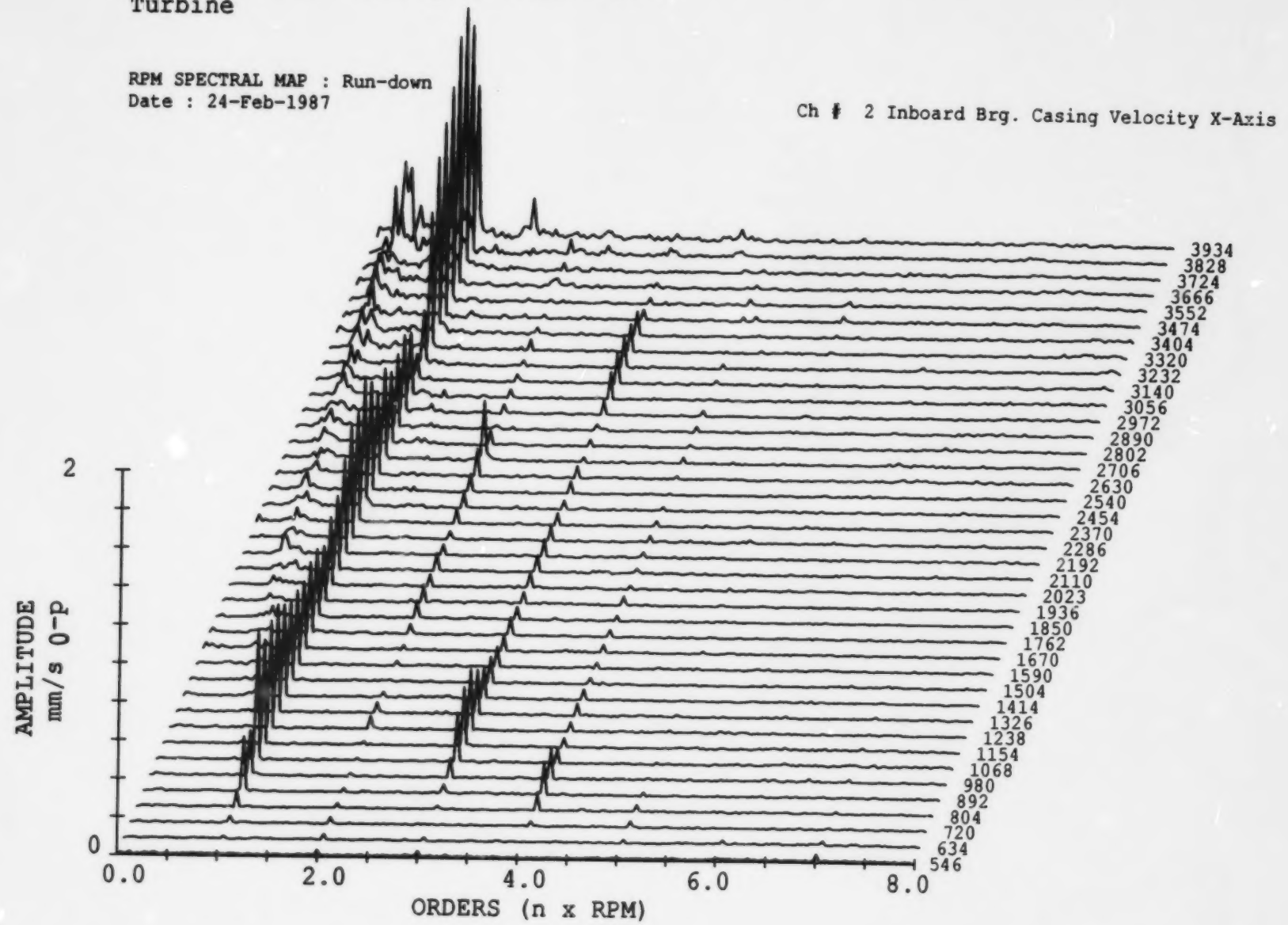


FIGURE 170

88-241

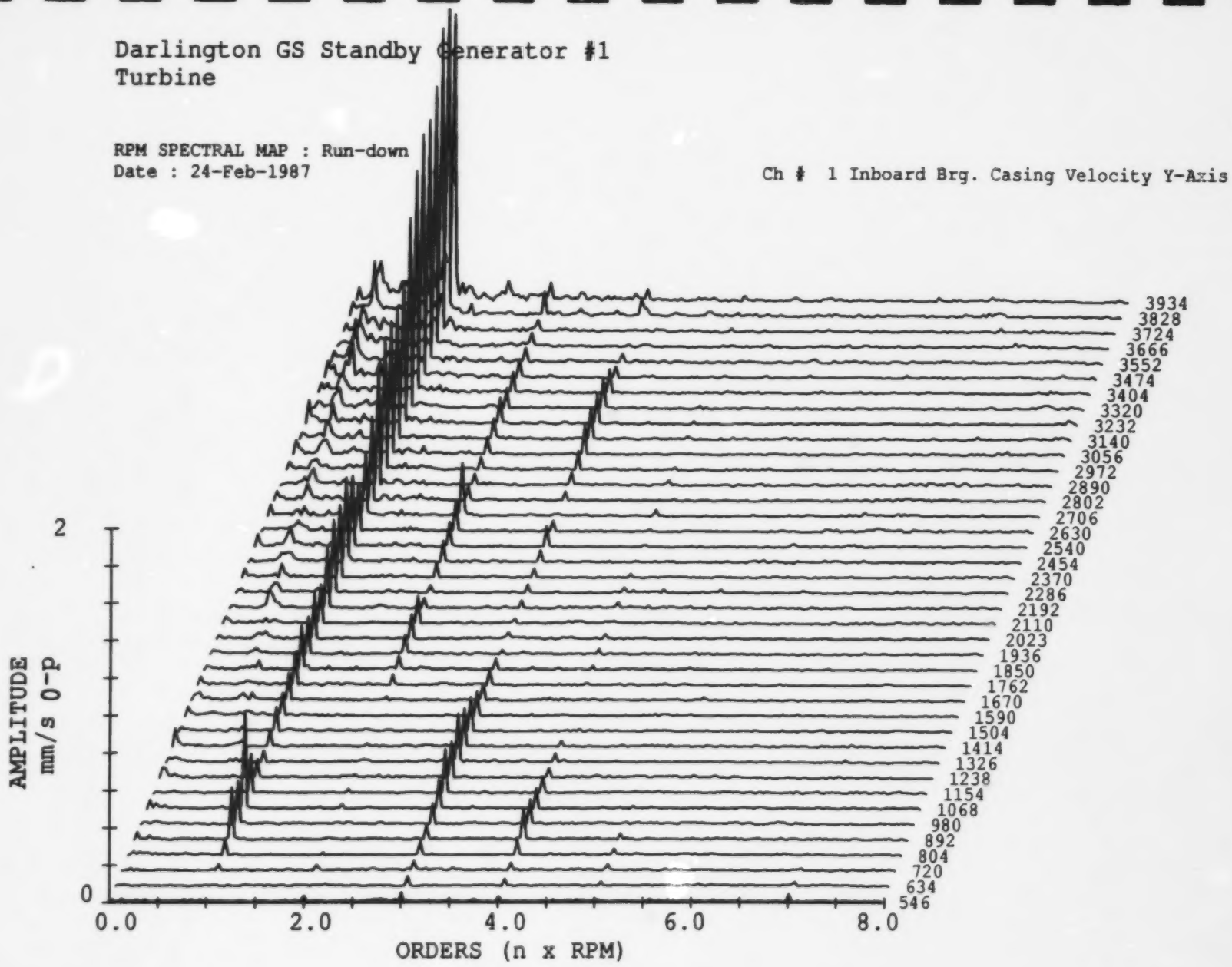


FIGURE 171
88-241

Darlington GS Standby Generator #1
Turbine

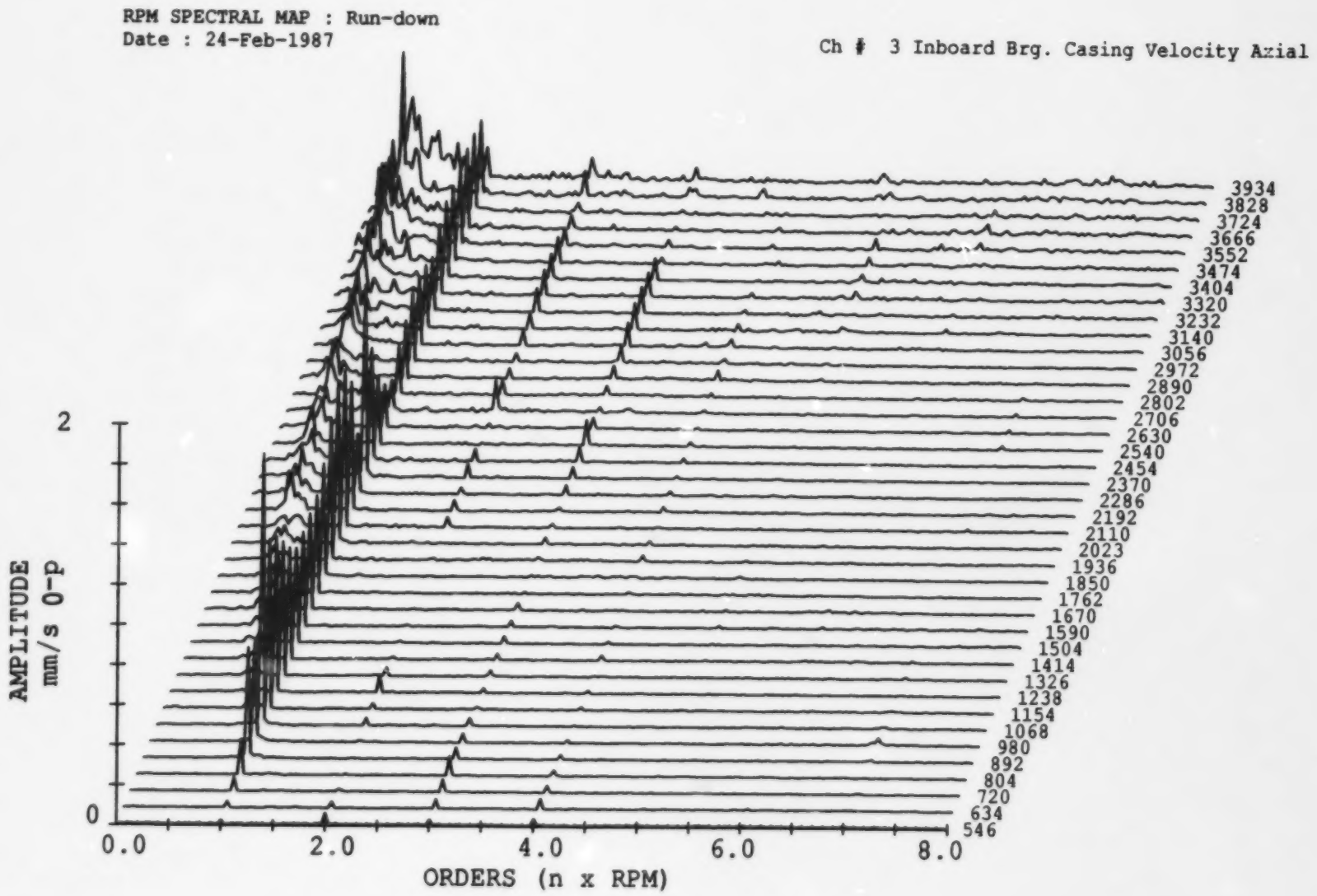


FIGURE 172
88-241

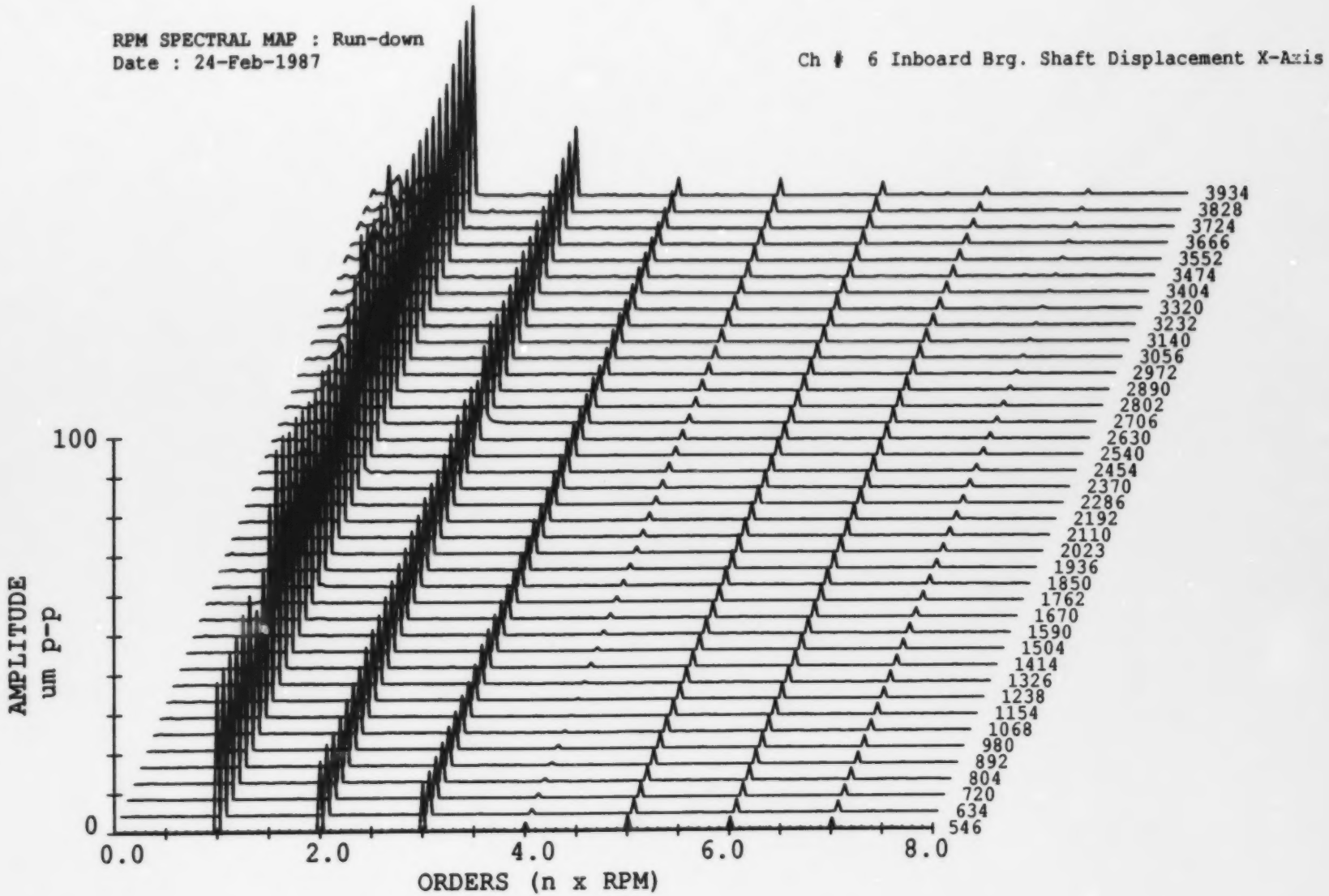


FIGURE 173
88-241

Darlington GS Standby Generator #1
Turbine

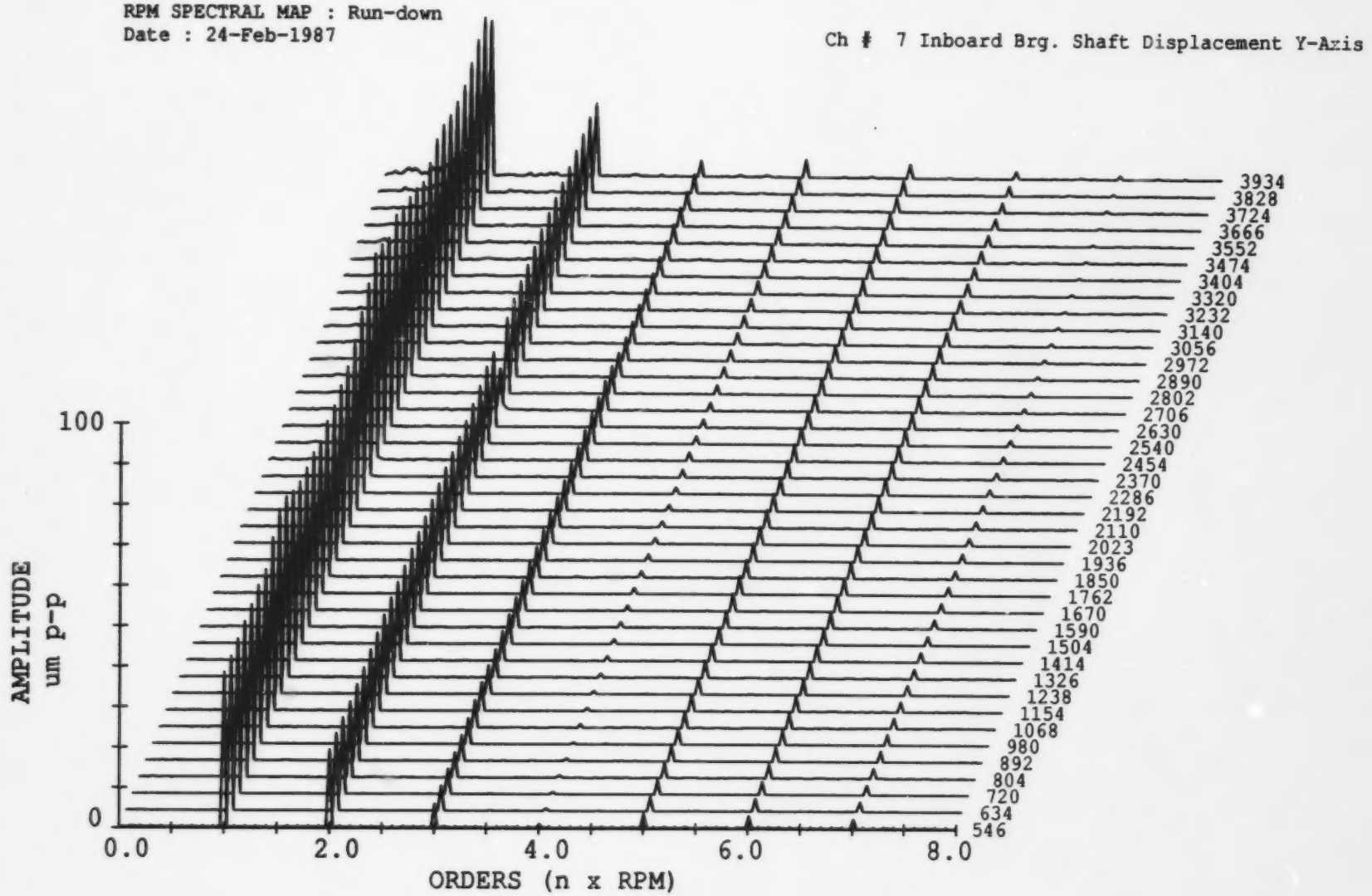


FIGURE 174
88-241

Darlington GS Standby Generator #1
Turbine

RPM SPECTRAL MAP : Run-down
Date : 24-Feb-1987

Ch # 8 Outboard Brg. Shaft Displacement X-Axis

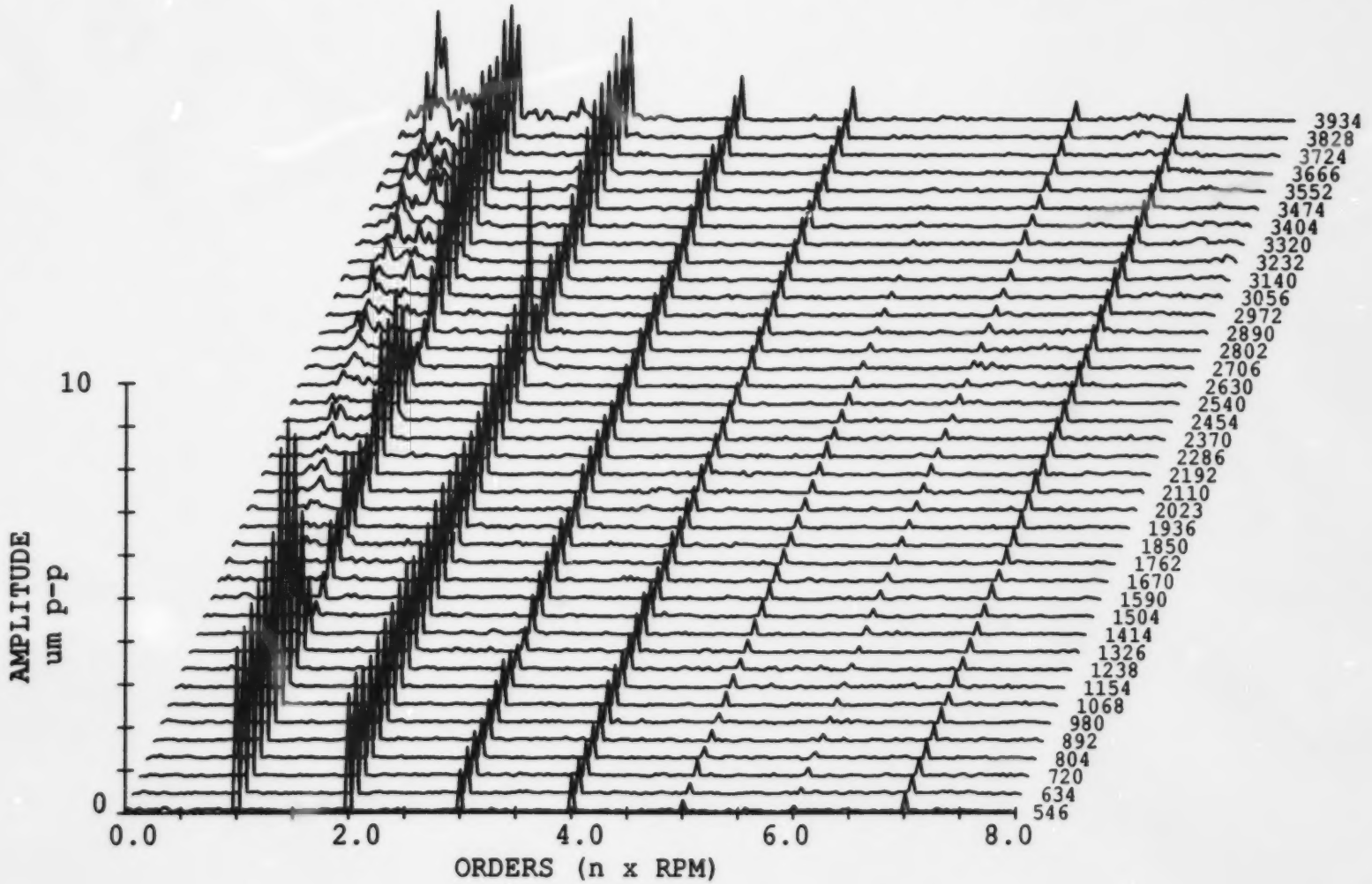


FIGURE 175
88-241

Darlington GS Standby Generator #1
Turbine

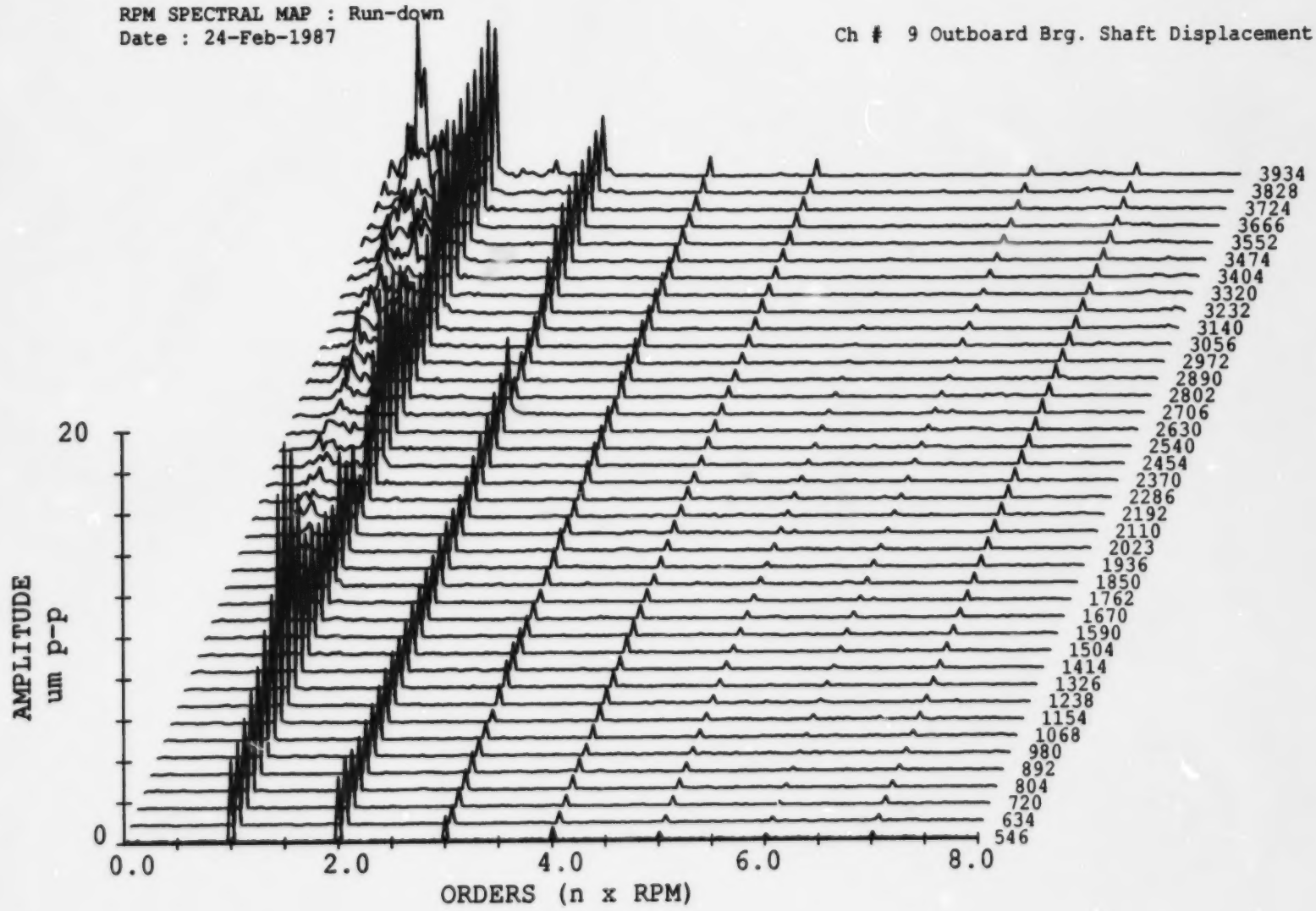


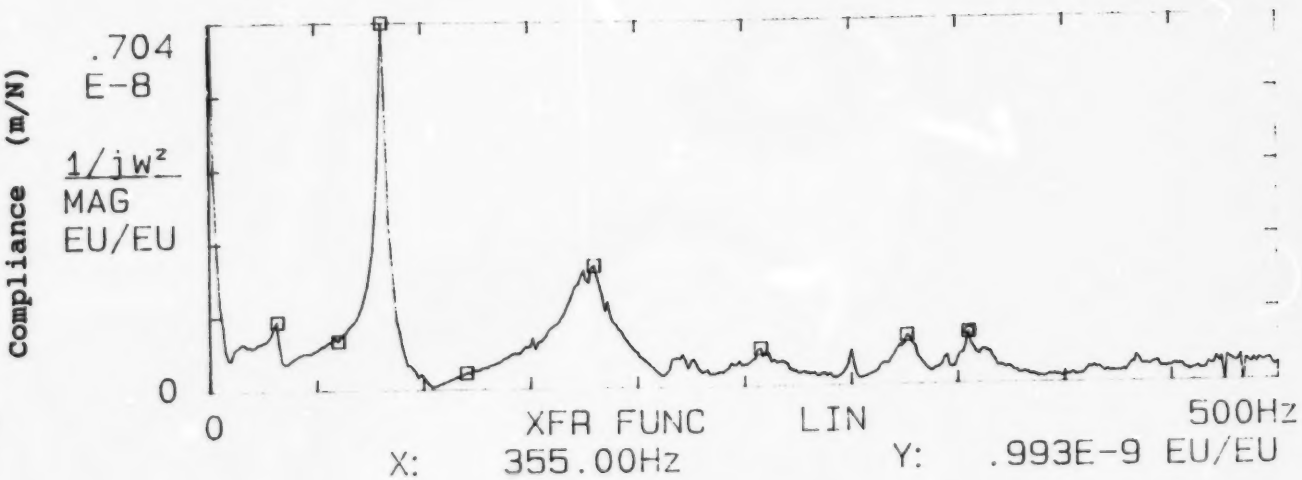
FIGURE 176

88-241

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR OUTBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#1 GEN OB HORIZ
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1K

		XFER FUNC MAG - PH	
1	31.25Hz	.134E-8 EU/EU	151.4 deg
2	60.00	.949E-9	179.6
3	81.25	.749E-8	104.9
4	120.00	.320E-9	172.6
5	180.00	.238E-8	84.2
6	257.50	.736E-9	47.2
7	326.25	.968E-9	115.9
8	355.00	.993E-9	141.3
9			
10			



Compliance (m/N)

FIGURE 177

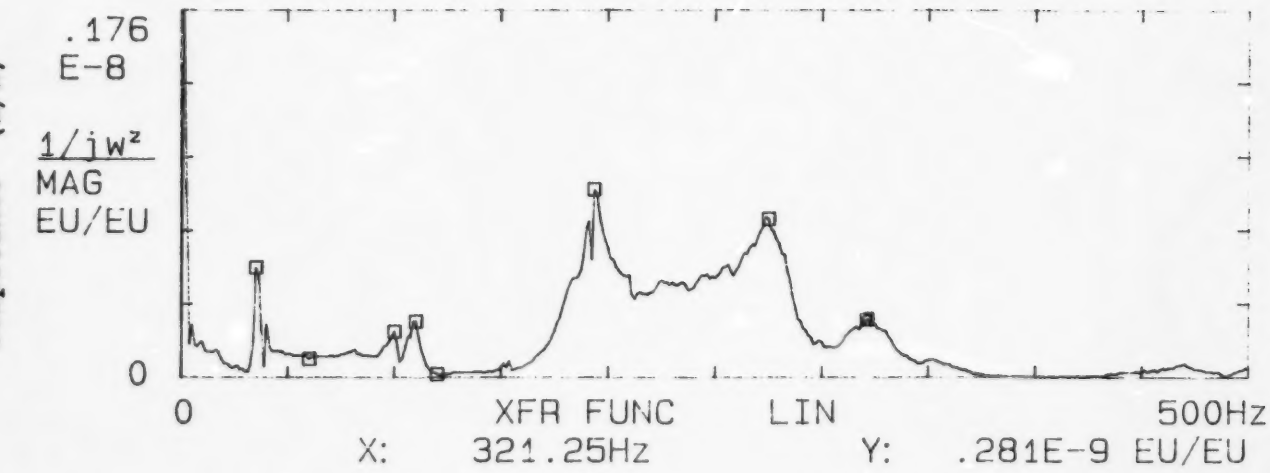
00: 47

88-241

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR OUTBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

DNGS SG#1 GEN OB VERT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG - PH	
1	35.00Hz	.530E-9 EU/EU	106.8 deg
2	60.00	.883E-10	.4
3	100.00	.222E-9	-37.2
4	110.00	.271E-9	-100.2
5	120.00	.181E-10	126.9
6	193.75	.907E-9	61.4
7	275.00	.763E-9	-59.9
8	321.25	.281E-9	-52.1
9			
10			



Compliance (m/N)

FIGURE 178

88-241

00: 50

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR OUTBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (AXIAL DIRECTION)

DNGS SG#1 GEN OB AXIAL
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG - PH	
1	35.00Hz	.126E-7 EU/EU	-60.5 deg
2	40.00	.474E-8	-132.2
3	60.00	.738E-10	-74.9
4	93.75	.193E-8	-75.3
5	120.00	.381E-9	-7.3
6	151.25	.180E-8	-21.7
7	183.75	.602E-8	-90.6
8	191.25	.879E-8	-135.6
9			
10			

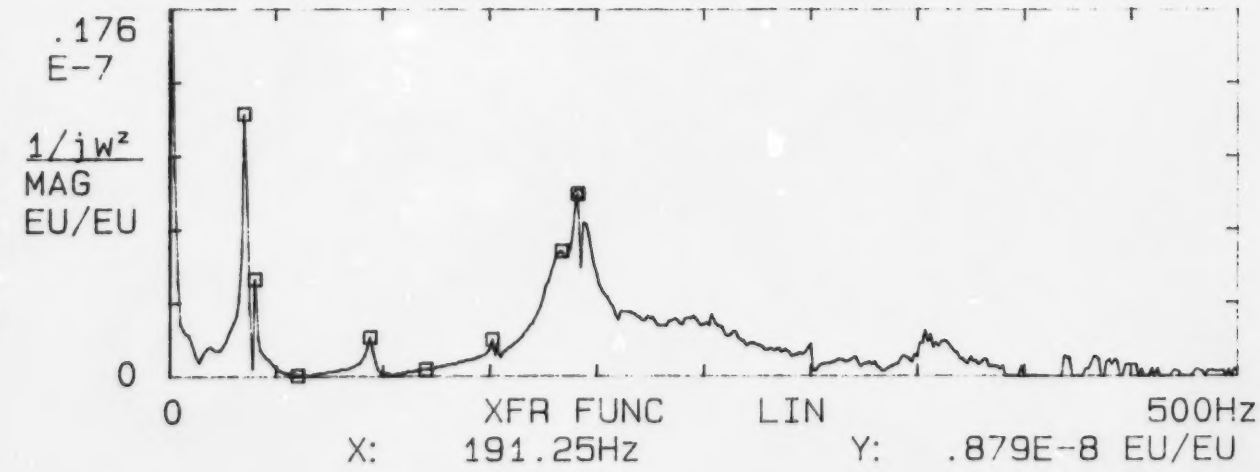


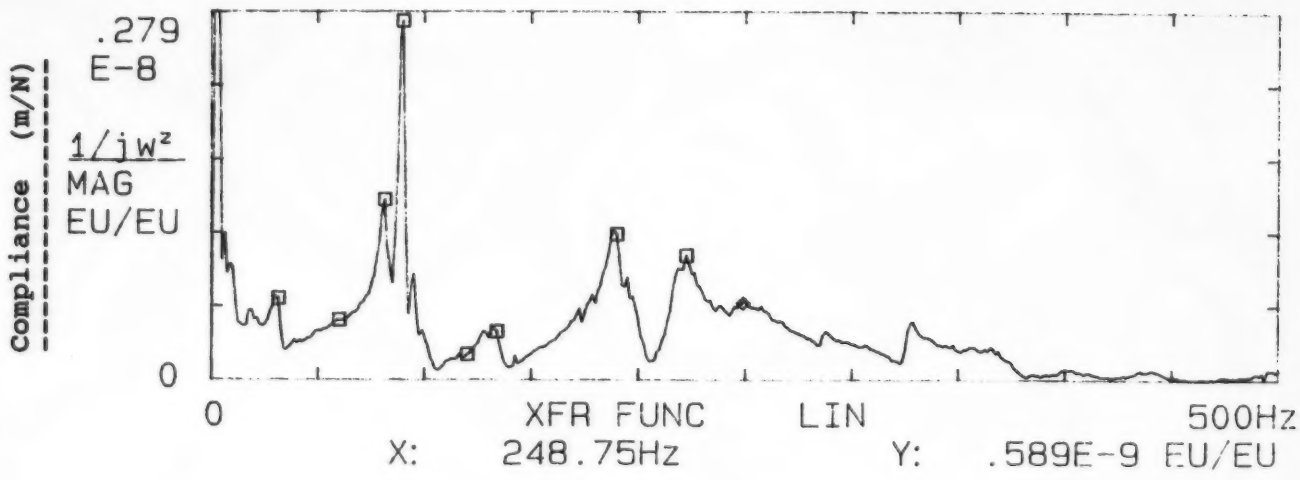
FIGURE 179

00: 55

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR INBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#1 GEN IB BRG HOUSING HORIZ IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG - PH	
1	31.25Hz	.620E-9 EU/EU	-33.2 deg
2	60.00	.459E-9	-.4
3	81.25	.137E-8	-41.2
4	90.00	.273E-8	-119.5
5	120.00	.198E-9	-33.7
6	133.75	.372E-9	-80.1
7	190.00	.111E-8	-94.9
8	222.50	.952E-9	-100.6
9			
10			



01:56

FIGURE 180

88-241

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR INBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

DNGS SG#1 GEN IB BRG HOUSING VERT IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG	- PH
1	16.25Hz	.267E-9 EU/EU	-10.1 deg
2	36.25	.293E-9	26.2
3	60.00	.135E-9	-10.7
4	108.75	.307E-9	-55.8
5	133.75	.143E-9	-62.9
6	182.50	.383E-9	86.7
7	202.50	.281E-9	12.0
8	276.25	.460E-9	-67.4
9	320.00	.365E-9	-69.1
10	352.50	.649E-9	-93.7

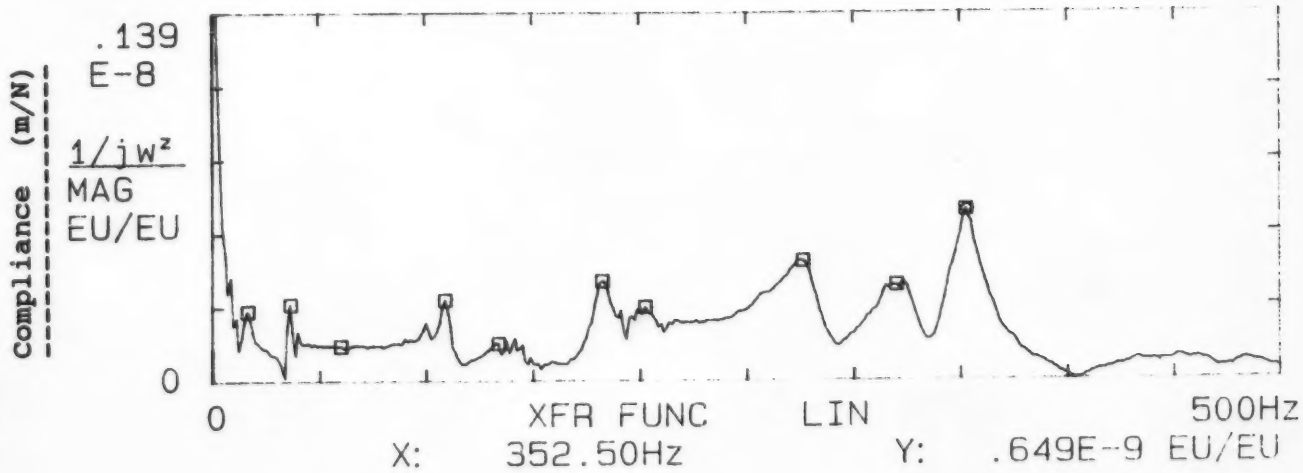


FIGURE 181

01:50

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR INBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (AXIAL DIRECTION)

DNGS SG#1 GEN IB BRG HOUSING AXIAL IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG - PH	
1	35.00Hz	.825E-8 EU/EU	-64.2 deg
2	40.00	.311E-8	-131.3
3	60.00	.121E-9	-9.7
4	92.50	.548E-9	-21.7
5	101.25	.572E-9	-84.4
6	120.00	.343E-9	-3.4
7	181.25	.160E-8	-76.3
8	195.00	.115E-8	-115.6
9	246.25	.972E-9	-91.3
10	371.25	.229E-8	-73.8

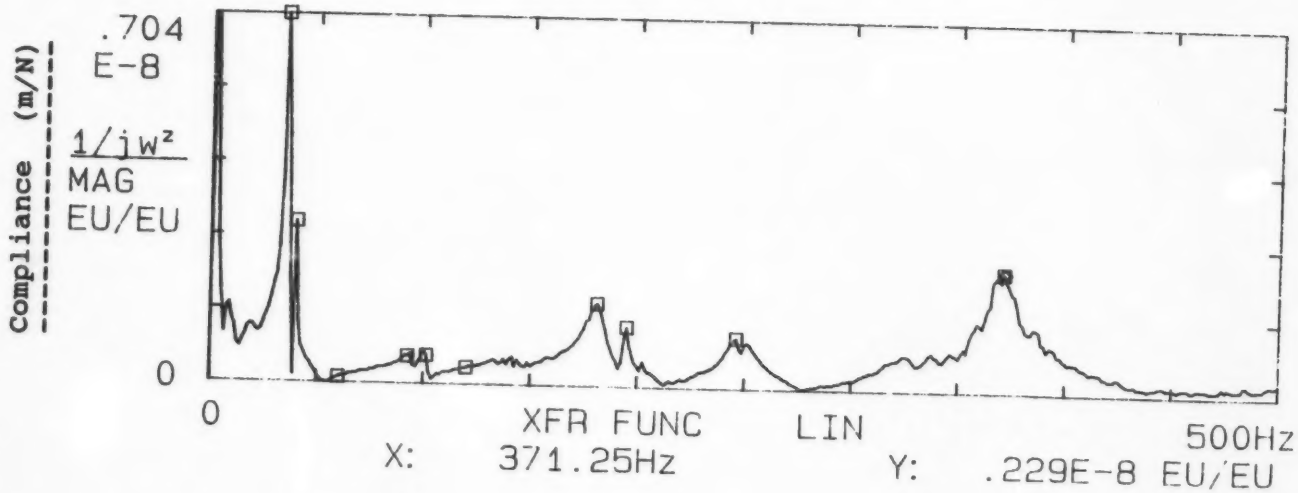


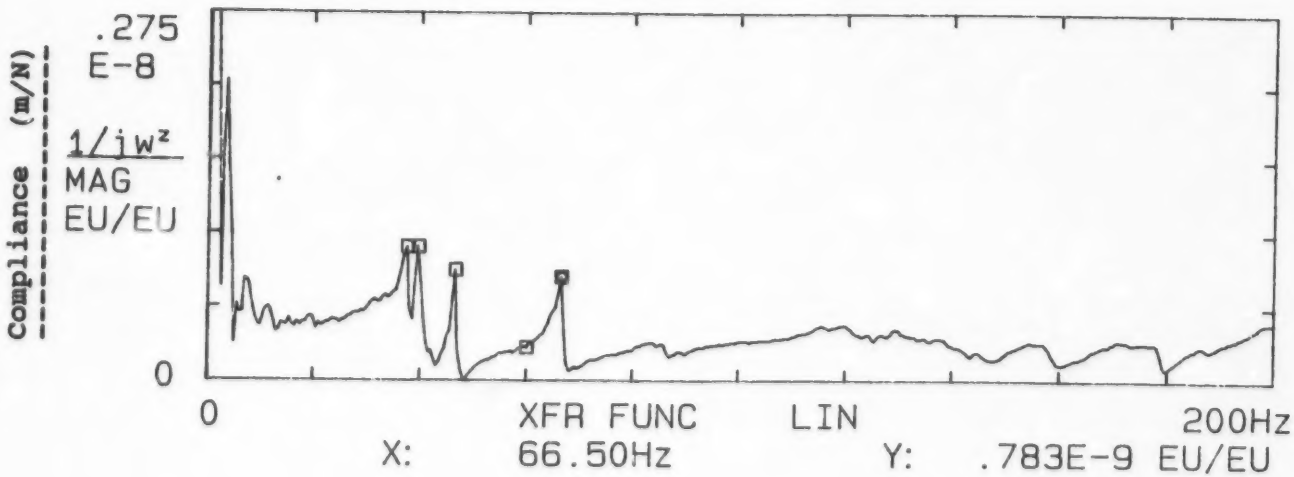
FIGURE 182

03: 15

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR FRAME COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#1 GEN BASE IB HOR ON BASE PLATE IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG	- PH
1	37.50Hz	.100E-8 EU/EU	-67.4 deg
2	39.50	.100E-8	-68.4
3	46.50	.834E-9	-112.9
4	60.00	.252E-9	7.6
5	66.50	.783E-9	-84.7
6			
7			
8			
9			
10			



01: 42

88-241 FIGURE 183

DARLINGTON GS 'A' STANDBY GENERATOR #1 - POWER TURBINE INBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#1 PWR TURB IB HORIZ IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG - PH	
1	25.00Hz	.864E-9 EU/EU	-70.1 deg
2	44.00	.103E-9	-40.0
3	59.00	.396E-9	-76.4
4	64.00	.288E-9	-128.6
5	74.50	.639E-10	-168.4
6	84.00	.830E-10	-140.6
7			
8			
9			
10			

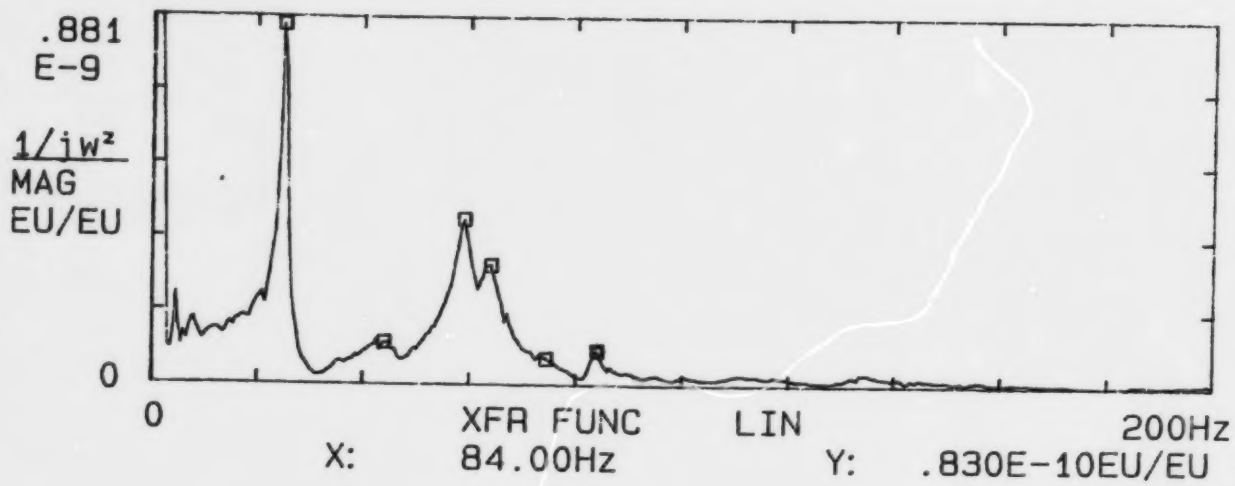


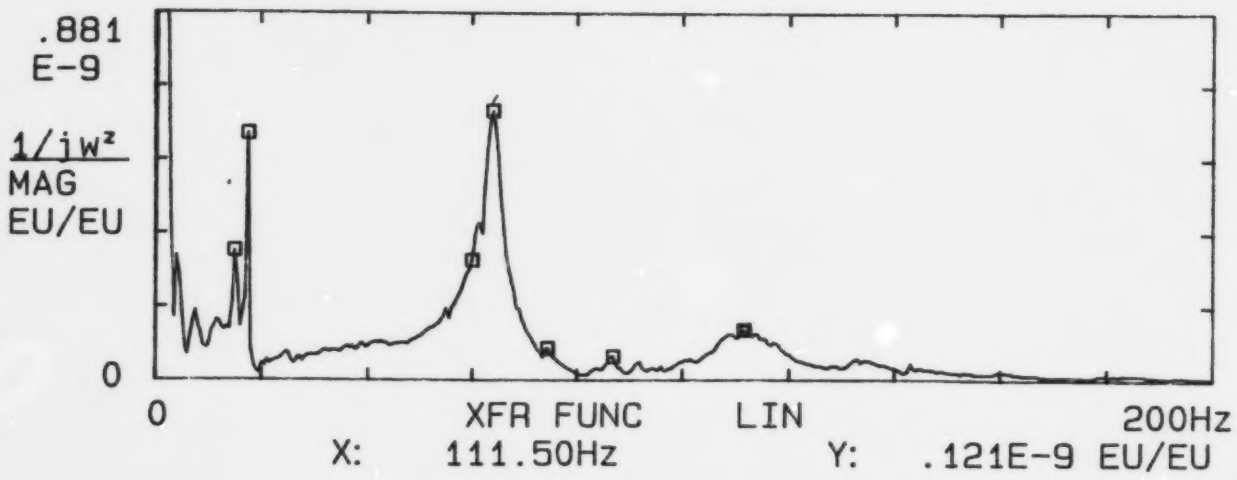
FIGURE 184 Compliance (m/N)

00: 31

DARLINGTON GS 'A' STANDBY GENERATOR #1 - POWER TURBINE INBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

DNGS SG#1 PWR TURB IB VERT IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG - PH	
1	15.00Hz	.313E-9 EU/EU	-5.1 deg
2	17.50	.594E-9	-87.2
3	60.00	.292E-9	-25.4
4	64.00	.648E-9	-85.6
5	74.50	.789E-10	-158.5
6	87.00	.586E-10	-107.1
7	111.50	.121E-9	-98.2
8			
9			
10			



Compliance (m/N)

FIGURE 185

00: 26

DARLINGTON GS 'A' STANDBY GENERATOR #1 - POWER TURBINE INBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (AXIAL DIRECTION)

DNGS SG#1 PWR TURB IB AXIAL IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG - PH	
1	17.50Hz	.398E-8 EU/EU	85.1 deg
2	25.00	.203E-9	118.8
3	39.50	.503E-9	111.2
4	43.50	.181E-8	84.2
5	60.00	.441E-10	3.0
6	84.00	.108E-9	53.2
7	134.00	.109E-9	69.0
8			
9			
10			

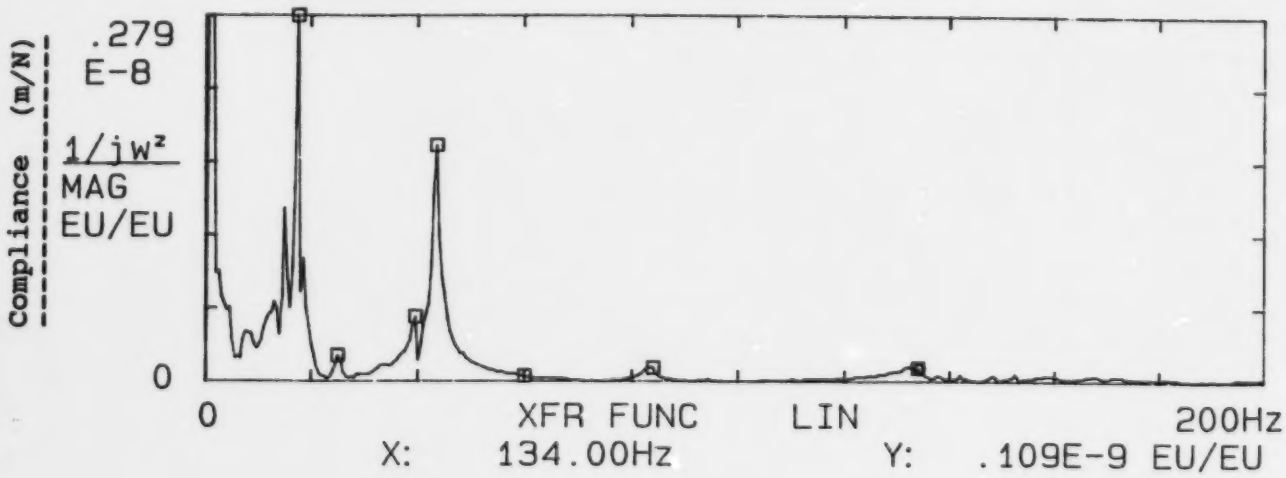


FIGURE 186

00: 36

88-241

DARLINGTON GS 'A' STANDBY GENERATOR #1 - POWER TURBINE SKID INBOARD END COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#1 SKID PWR TURB END WEST SIDE HORIZ IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

		XFER FUNC MAG - PH	
1	25.00Hz	.141E-9 EU/EU	-148.1 deg
2	45.00	.470E-10	-41.7
3	58.00	.148E-9	-94.9
4	60.00	.650E-10	-74.6
5	62.00	.174E-9	-114.6
6	82.50	.752E-10	-89.0
7	93.00	.863E-10	-51.0
8	98.50	.164E-9	-107.1
9	109.00	.102E-9	-111.6
10			

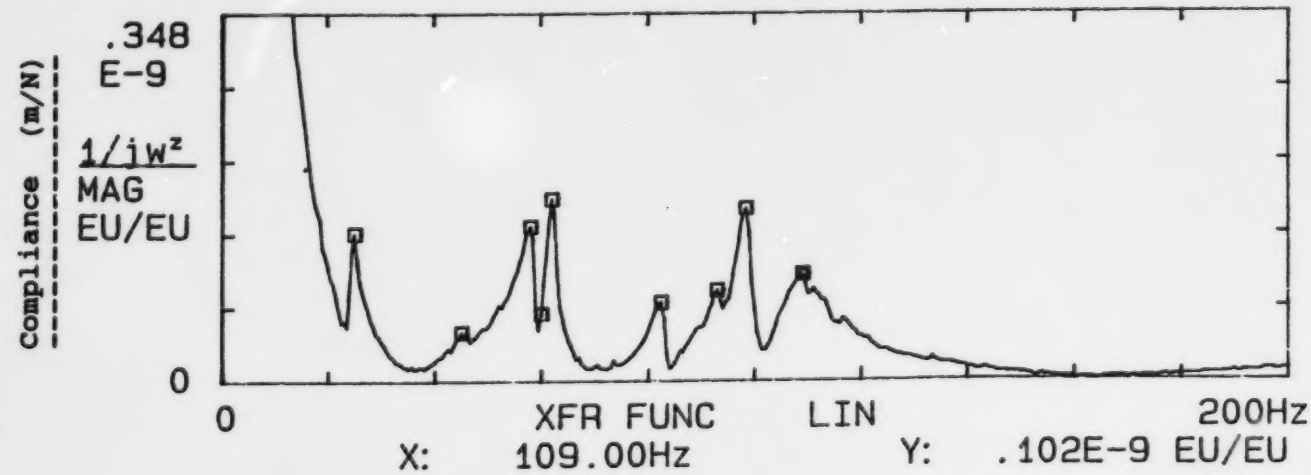


FIGURE 187

88-241

01:28

DARLINGTON GS 'A' STANDBY GENERATOR #1 - POWER TURBINE SKID INBOARD END COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

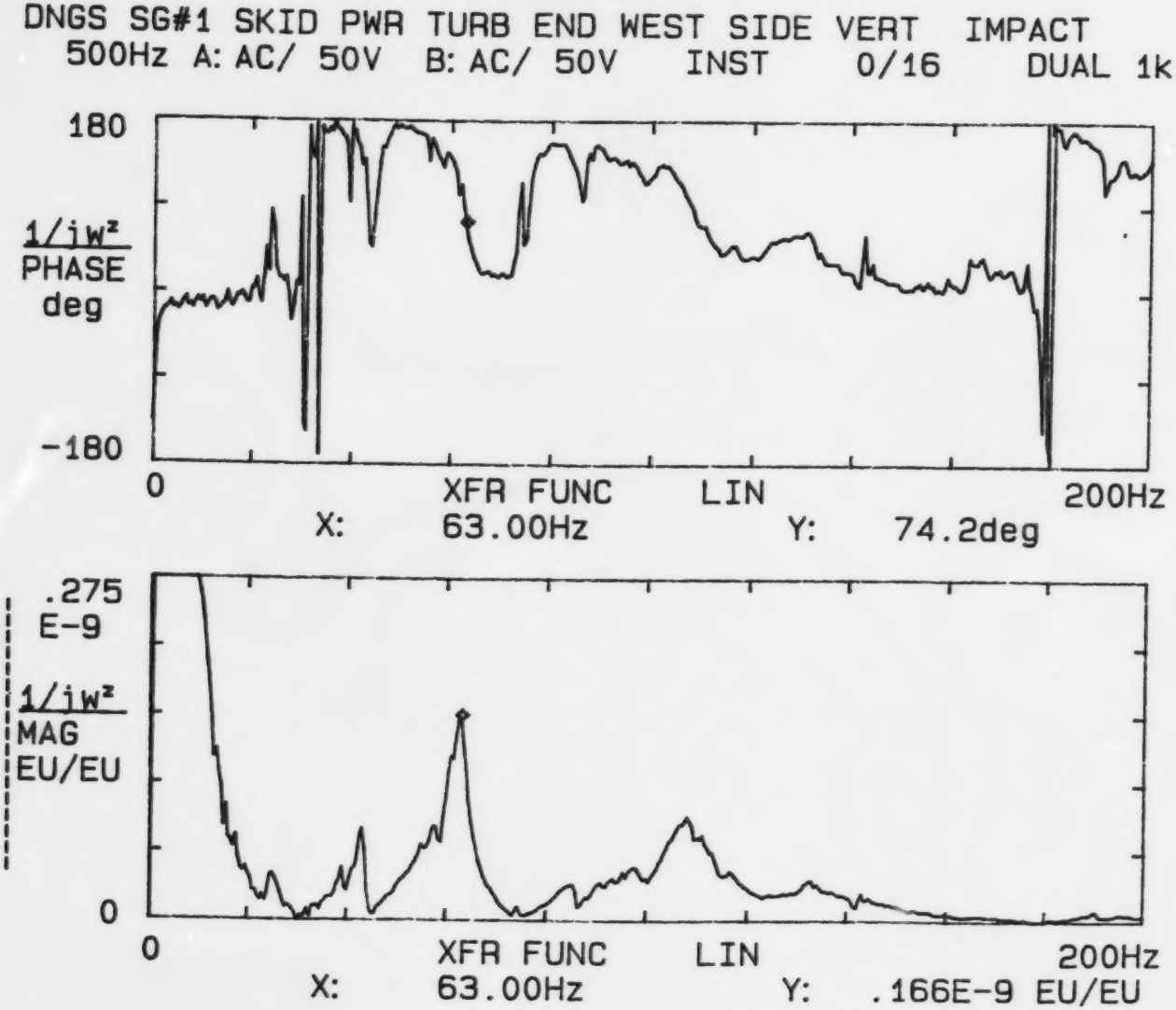


FIGURE 188

88-241

01: 33

DARLINGTON GS 'A' STANDBY GENERATOR #1 - POWER TURBINE INBOARD BEARING SHAFT DISPLACEMENT TIME SIGNAL SHOWING 'GLITCH'

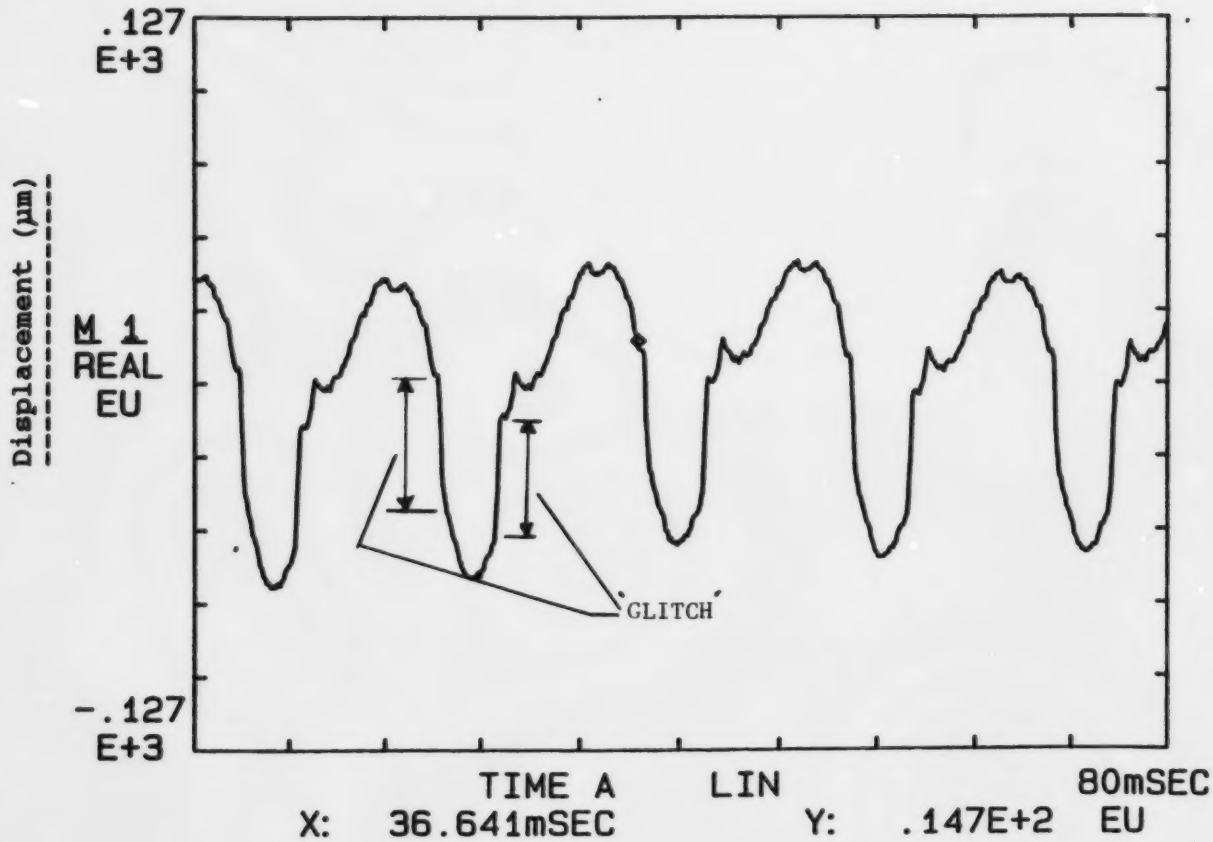


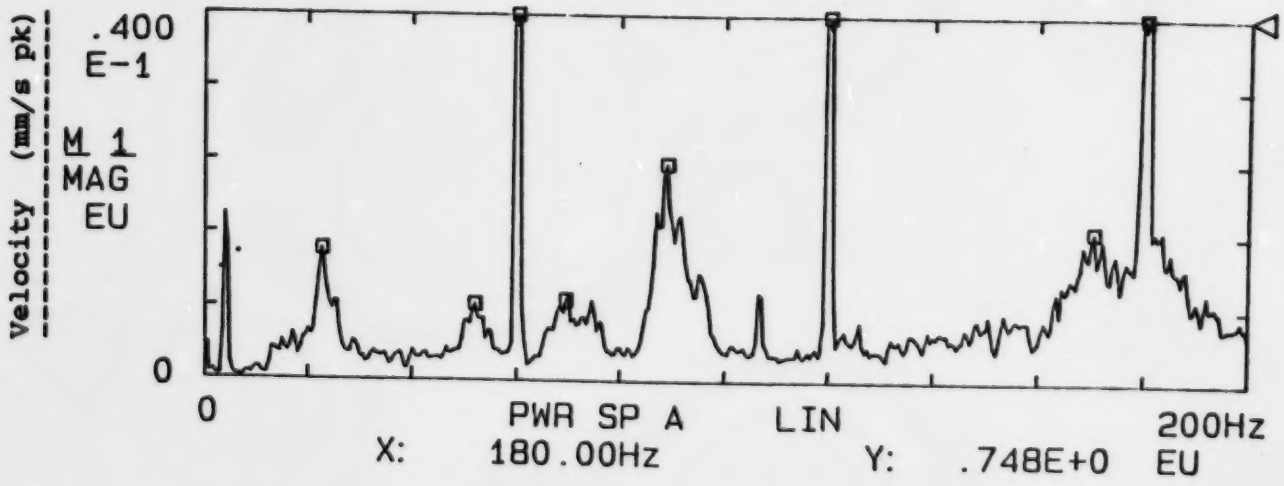
FIGURE 189

88-241

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR OUTBOARD BEARING CASING VELOCITY SPECTRUM (Y-DIRECTION)

DNGS SG#1 GEN CH 1 26 MW 02: 20
200Hz A: AC/0.2V B: AC/0.5V S.SUM 0/32 DUAL 1k

	PWR SPECTRUM	ChA	
1	22.50Hz	.143E-1	EU
2	52.00	.841E-2	
3	60.00	.284E+0	
4	69.50	.895E-2	
5	89.00	.238E-1	
6	120.00	.283E+0	
7	170.50	.167E-1	
8	180.00	.748E+0	
9			
10			



00: 11

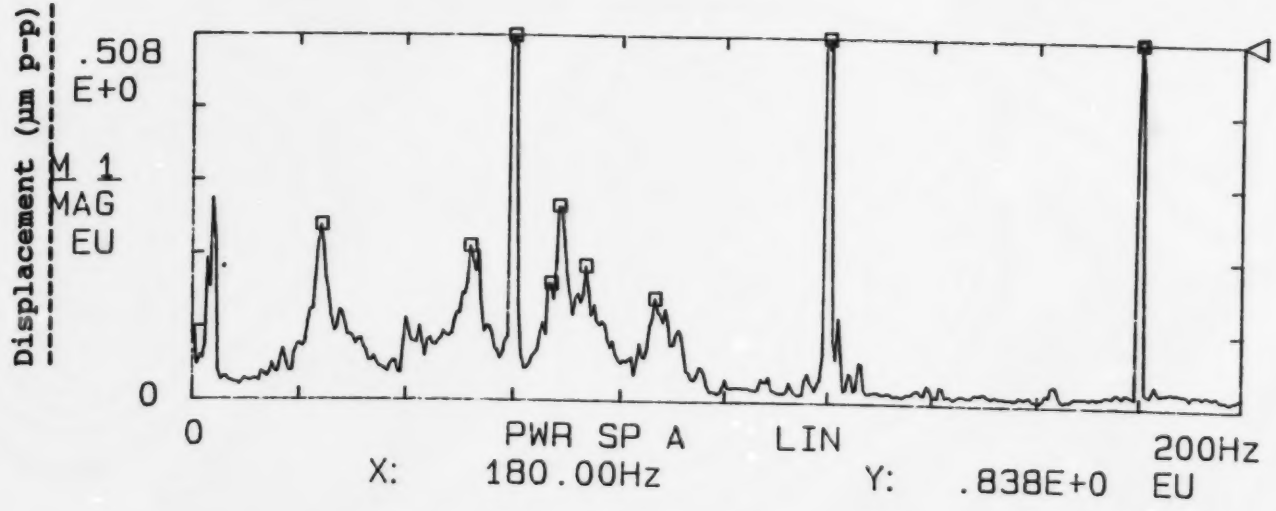
FIGURE 190

88-241

DARLINGTON GS 'A' STANDBY GENERATOR #1 - AC GENERATOR OUTBOARD BEARING SHAFT DISPLACEMENT (Y-DIRECTION)

DNGS SG#1 GEN CH 8 26 MW 02: 25
200Hz A: AC/0.2V B: AC/0.5V S.SUM 0/32 DUAL 1k

	PWR SPECTRUM	ChA	
1	24.00Hz	.245E+0	EU
2	52.00	.215E+0	
3	60.00	.159E+2	
4	67.00	.165E+0	
5	68.50	.272E+0	
6	73.50	.189E+0	
7	86.50	.143E+0	
8	120.00	.827E+1	
9	180.00	.838E+0	
10			



00: 44

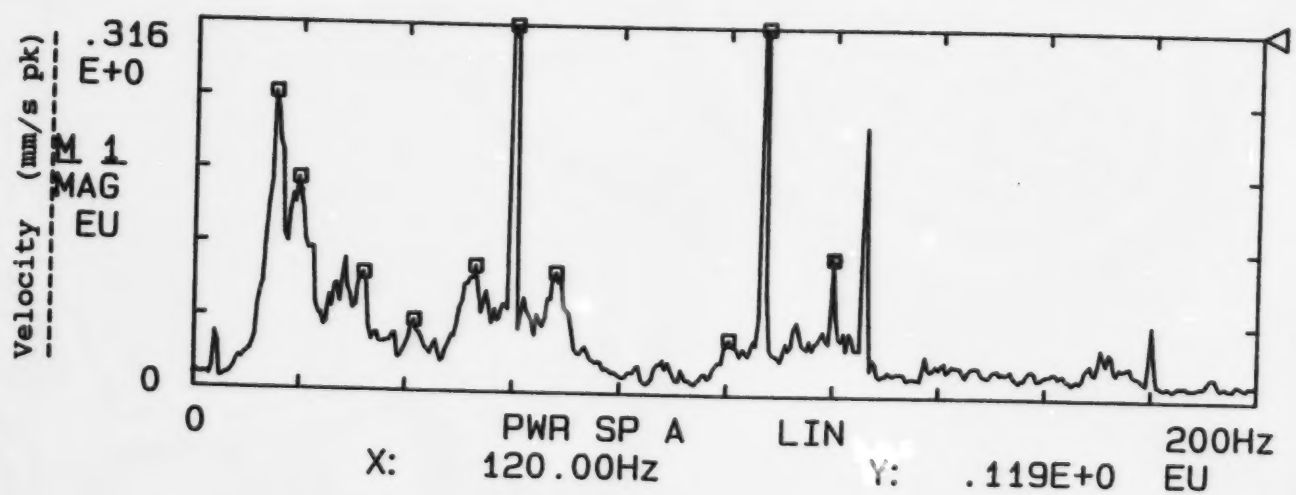
FIGURE 191

88-241

DARLINGTON GS 'A' STANDBY GENERATOR #1 - POWER TURBINE INBOARD BEARING CASING VELOCITY SPECTRUM (X-DIRECTION)

DNGS SG#1 PWR TURB CH 2 26 MW 00: 29
2kHz A: AC/0.5V B: AC/0.5V INST 0/32 DUAL 1k

	PWR SPECTRUM	ChA	
1	15.00Hz	.257E+0	EU
2	19.50	.183E+0	
3	32.00	.103E+0	
4	41.50	.616E-1	
5	53.00	.110E+0	
6	60.00	.157E+1	
7	68.00	.104E+0	
8	100.50	.486E-1	
9	107.00	.333E+0	
10	120.00	.119E+0	



00: 05

FIGURE 192
88-241

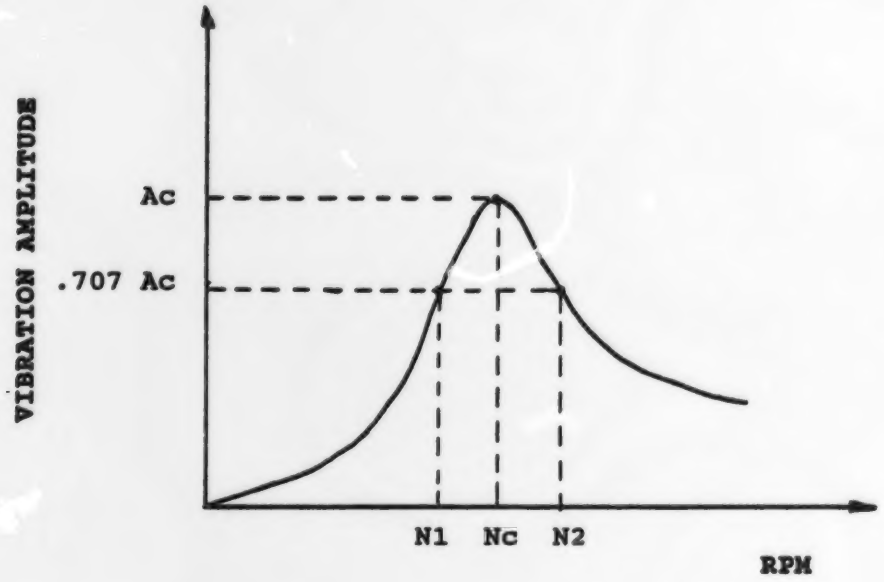
APPENDIX A

COMPENSATION

A Bode plot will be distorted if the signal from the displacement transducer includes any appreciable amount of shaft bow or runout (any deviation in the observed shaft surface which produces a transducer output which is not related to shaft motion). Both shaft bow and runout will create an initial vector or offset in the phase and amplitude portions of the Bode plot. As the shaft speed changes, the bow or runout value (presumably a constant) vectorially combines with true shaft motion to produce the total signal sensed by the transducer. If the bow or runout is a significant portion of the total signal, the appearance of the Bode plot can be greatly altered. These alterations or distortions may include an amplitude peak and phase shift well removed from the actual critical speed, dips in amplitude rather than peaks, or no response in extreme cases.

To circumvent this problem, the displacement transducer signal at a slow shaft speed is obtained and stored. As the shaft speed changes, the slowroll displacement signal can be subtracted from the total displacement signal to yield a signal compensated for shaft bow and runout.

APPENDIX B
DETERMINING AMPLIFICATION FACTORS



Nc = Rotor critical centre frequency (cycles/minute)
N1 = Initial (lesser) speed at 0.707 x peak amplitude (critical)
N2 = Final (greater) speed at 0.707 x peak amplitude (critical)
Ac = Amplitude at Nc

$$AF = \text{Amplification Factor} = \frac{Nc}{N2 - N1}$$